STEAM SHIP CAPABILITY

BY

CHARLES ATHERTON.

STEAM SHIP CAPABILITY.

THE CAPABILITY OF STEAM SHIPS,

BASED ON THE MUTUAL RELATIONS OF

DISPLACEMENT, POWER, AND SPEED;

ILLUSTRATED BY

TABLES,

ADAPTED FOR

MERCANTILE REFERENCE.

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PREFACE.

In explanation of the object sought to be attained by the publication of the following Treatise, it may be premised that Shipping may now be regarded as in a state of transition; for, though the use of Sail may not be superseded by the agency of Steam, it seems apparent that the co-operation of sail and steam will be universally introduced. Under this aspect of shipping interests, it is desirable that the public have the means of becoming familiar with the mutual relation of Steam-ship Displacement, Power, and Speed, in order that the conditions of Steam-ship mechanical and nautical efficiency may be foreknown, and that the commercial balance account between estimated Speed and Cost may be duly calculated: in short, it is the compound combinations of Displacement, Power, and Speed, in relation to the Cost of Freight, which constitute the arithmetic of Steam-ship adaptation to the requirements of mercantile service.

Thus, to bring under view the mutual relations of Steam-ship Displacement, Power, and Speed, with reference to the Cost of Freight, is the task that has been attempted in this Essay. The results can only be regarded as approximate; and the system of calculation is admissibly still open to corrective research; but, being based on generalized data, derived from practical experience, it is expected that the Work will present a substantially

correct digest of the CAPABILITIES of Steam as now applied to Navigation; and that it will point out a course of investigation not hitherto thrown open, and on which much labour may be usefully bestowed.

The primary matter, however, necessarily brought forward for consideration as being the base of all Steam-ship calculations as respects the mutual relation of Power and Speed, and therefore, indispensable to the prosecution of these inquiries, is a proposition for assigning some *definite* and *legalized* STANDARD VALUE to the term HORSE-POWER as the UNIT of power applicable to Steam-ship Navigation; by which Constant Quantity, marine engine contracts may, as regards the measure of power, be assimilated, and by which the available ENGINE-POWER of all steamers may be duly registered together with the Tonnage and the Displacement of the ship at a given draught; but this proposition is of a nature that can only be dealt with by legislative authority on representations backed by the greatest commercial weight; and should this Essay promote the realisation of a step so essential in the progress of *systematizing* the science of Steam-ship construction, and of Steam-ship adaptation and management, its publication will have conduced to public utility in a department of national enterprise of the utmost importance to the manufacturing and mercantile interests of the country.

CHARLES ATHERTON.

Woolwich Dockyard,
1*st. March*, 1853.

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Section V., page 61 to 72.—Investigation as to the comparative extent to which the Cost of Freight *per ton* is affected by differences of original Construction as regards the Locomotive Properties of different ships, or by different degrees of *falling off* in the working condition of the Hull, Engines, and Boilers of the same ship.

APPENDIX.

Exemplification of a method of constructing Diagrams, whereby the mutual relation of Displacement, Power, and Speed in vessels of analogous construction becomes generalized for all sizes of vessel within the range of the Scale on which the Diagram may be constructed.

Table *showing the number of* revolutions *per minute which will be required in order that a Screw-Propeller of a* given pitch *may advance at a* given speed *per hour, slip not included.*

ERRATA.

Page 15—Last line of Table D, for "3822," read 2822.

Page 28—Line 2, for $\frac{\text{"H.P."}}{182{\cdot}000}$, read $\frac{\text{P.V.}}{182{\cdot}000}$.

Page 52, 53, and 54—For "Index Number 871," read 862.

THE MUTUAL RELATIONS

OF

STEAM SHIP

DISPLACEMENT, POWER, AND SPEED;

ILLUSTRATED BY

TABLES

ADAPTED FOR

MERCANTILE REFERENCE.

SECTION I.

THE NOMINAL HORSE-POWER GENERALLY REFERRED TO IN STEAM-SHIP NAVIGATION AND REGISTERED AS THE ENGINE-POWER, DOES NOT DEFINE THE MOTIVE POWER CAPABLE OF BEING DEVELOPED BY THE ENGINES. NECESSITY FOR DETERMINING UPON SOME SPECIFIC AND EASILY MEASURABLE AMOUNT OF POWER TO BE ASSIGNED TO THE TERM HORSE-POWER, AND ADOPTED AS THE STANDARD MEASURE IMPLIED BY THAT TERM.

At a period when Steam Ship navigation is being prosecuted with unprecedented energy; when vessels of stupendous magnitude are being projected with a view to the circumnavigation of the globe; when a value is assigned to time, which urges the realization of speed to a degree which can be obtained only by the expensive resources of art being applied, not merely to co-operate with, but even to supersede the spontaneous but uncertain power of the wind; when commercial enterprise is thus

incurring the hazards of a new order of pecuniary investment, which may be beneficial or adverse to national interests according as prudence and skill, or indiscretion and error, may characterize the originating and conducting of such affairs; when moreover in such affairs, prosperity or loss depend on the discrimination with which the issues of Speed and Cost may be balanced against each other: under these circumstances, it may be expected that any attempt to illustrate, though but approximately, the mutual relation of the elements on which Steam Navigation is dependent, will be favorably entertained. With this hope, the following Tables showing approximately the mutual relation of Displacement, Power, Speed, and Cost, have been prepared and published.

Preparatory to the construction of these Tables, our primary object must be to determine upon some specific and measurable amount of motive power, to be assigned to the term horse-power (H.P.), and adopted as the base of calculation. It is to be observed that the definite measure of power originally implied by the term horse-power has, in marine practice, become totally superseded: the term horse-power, as now applied in marine engine contracts and practice, does not specifically determine, or limit, the gross working-power of the engines; but, the difference of working-power between one engine and another, though both, nominally, of the same horse-power and contracted for as such, can be shown to have been as much as 100 per cent.: that is, the one working up to double the power of the other; or, in other words, though marine engine contracts may have specifically fixed the *nominal* horse-power and the amount of money to be paid thereon, they have afforded no guarantee for the amount of *working* horse-power to be delivered; but the working-power has been left, in great

measure, to the voluntary discretion of the engine manufacturer.

Such discrepancies, which naturally result from contracts specifically binding only on one side, namely, as regards the amount of money to be paid, surely point out the necessity for the adoption of some system of commercial regulation in respect to the purchase and delivery of engine-power, whereby steam-ship INVESTMENT may be regulated more approximately in accordance with the accuracy of calculation, that generally distinguishes the prosecution of commercial enterprise.

The discrepancies above described between the nominal and the working-power of marine engines, are the more remarkable when it is considered that they are not attributable to the engines being produced by different makers, but apply to engines supplied under contract by the same manufacturers, and those of the highest repute, and even paid for at about the same rate per nominal horse-power, (for it is the nominal H.P. that generally rules the price), though producing, in effect, a difference of 100 per cent. and upwards on the cost of the *working-power*. Nevertheless, the term horse-power, from its seeming definiteness and simplicity, has become in the public mind so inveterately identified with marine engines, as describing proportionally the amount of their working-power, that any attempt on the present occasion to correct that delusive impression by altogether superseding the term horse-power, would be abortive, and probably defeat the desired utility of the present work as a Mercantile Tabular Reference: it is therefore proposed to retain the use of the term horse-power (H.P.) but to assign to it a *definite* and *measurable* value, corresponding to the ascertained Measure of the Working or Motive-power that on special

cases of the most successful engineering practice wherein the reputation of rival manufactures has been at stake, has been duly delivered and put into practical operation under that denomination; deducing an average of the working-power in such cases, not from the performance of a particular engine of a particular maker, but embracing a whole class of vessels of which the engines are the productions of various manufacturers.

In presenting these Tables with a view to so general a purpose as the introduction of an uniform system of engine-power-admeasurement as the base of marine engine contracts, and for the regulation of commercial transactions, it is proper to announce the specific examples of marine engine practice which have been assumed as constituting a measure of horse-power, in accordance, as above stated, with the most effective adaptation of the present day: accordingly, the measure of power now proposed to be assigned to the term horse-power is based on the average that has been actually produced by the Government Mail Packets *Banshee*, *Llewellyn*, *Caradoc*, *Vivid*, *Garland*, *Violet*, *Onyx*, *Princess Alice*, *Undine*, and *Elfin;* in which examples of marine engine performance it will be found that, if we take in each case, the pressure on the piston in pounds (p), as ascertained on trial by the Indicator, multiplied by the velocity of the piston in feet per minute (v), and divide by 132·000, the result will, on the average, give the Nominal horse-power at which the engines of the above-named ten vessels were contracted for, and have been duly fitted by the manufacturers, after deducting 15 per cent. in consideration that the engines, (or rather the boilers), when on trial, may probably have been urged to the extent of 15 per cent. beyond the limits that would

be maintained for continuous work: as shown by the following:—

STATEMENT No. 1.

SHOWING THE NOMINAL HORSE-POWERS OF TEN PACKETS, AS CONTRACTED FOR, AND THE WORKING POWERS ACTUALLY PRODUCED.

Names.	Nominal Horse-power per Contract.	Working power as determined on Trial, expressed in pounds pressure on the piston, moving at the rate of one Foot per minute.
Banshee	350	57·816·000 lbs. 1 Foot per minute.
Llewellyn	350	58·179·000
Caradoc	350	52·800·000
Vivid.................	160	25·179·000
Garland	120	17·655·000
Violet	120	19·536·000
Onyx..................	120	17·699·000
Princess Alice ...	120	14·190·000
Undine	110	14·619·000
Elfin	40	8·085·000
Total	1840	285·758·000 lbs. 1 ft. per minute.

Deduct 15 per cent .... 42·863·000 (nearly)

242·895·000

Average per Horse-power (H.P.) $= \dfrac{242{\cdot}895{\cdot}000}{1840} =$ 132·000 lbs. 1 ft. per minute.

Hence, therefore, it appears that, in accordance with the engine performance of the ten vessels above referred to, a *marine horse-power* may be required to be the resultant of a pressure on the piston equivalent to 132·000 lbs., moving at the rate of one foot per minute; and it is proposed that such shall be the measure of power represented by the term horse-power (H.P.),

as applied to marine steam engines; and that, whenever the term horse-power (H.P.) is referred to, whether it be the nominal horse-power referred to in the contract, or the indicated horse-power as ascertained by aid of the Indicator, or the effective horse-power as ascertained by aid of the Dynamometer, it shall be determined, as above described, by the divisor 132·000, and not by the divisor hitherto partially in use, (namely, 33·000); as this latter divisor, however appropriate it may have been at the period of its introduction and application to land-engine purposes, is now, (as shown by the foregoing statement, No. 1,) altogether superseded by engineering practice as applied to steam navigation.

In the examples of marine-engine performance above referred to, the cubical capacity of the cylinders for steam appears, on the average, to be about three-fourths of a cubic foot per horse-power, the steam being used at full pressure to about three-fourths of the stroke: it is, however, not proposed, in the present instance, to make any attempt to regulate or control, the details of practical construction; the conditions as regards the size of the cylinder per horse-power, steam-pressure in the boiler, expansion in the cylinder, and working velocity of the piston at which the above measurable amount of motive power, per horse-power, is to be obtained, also the guaranteed ratio between the indicated horse-power as measured on the piston by aid of the Indicator, and the effective horse-power as determined by the Dynamometer, as well as the details of boiler construction, or the consumption of fuel with reference to the indicated H.P. determined as above deduced, may, optionally on the part of the purchaser, either be made the subject of specification and agreement, or be left to the judgment of a specially selected steam-ship contractor, thereby leaving an open field for

improvement and skill; for on these and other like details of construction, the durability, trustworthiness and upholding cost of the engine, and economy of fuel, in proportion to the effective power, will be materially dependent: the only object now sought to be subjected to regulation is simply this; that a HORSE-POWER (H.P.), shall signify *some* standard measure of motive power applicable to the present state of marine-engine practice; so that a contract, which specifically defines the price at which an engine is to be paid for, per horse-power, and the engine-power at which the ship is to be registered, or nominally pass current, shall also guarantee some definite amount of power being delivered, and not leave the amount of motive power indefinite to the extent of 100 per cent., as at present, to the confusion of marine engineering as a scientific profession, to the subversion of manufacturing competition, to the defiance of all calculation as to steam-ship capability, to the derangement of mercantile speculation in matters of steam-ship investment and management, and to the utter misrepresentation of the data on which the rate of insurance, so far as dependant on the registered power of the engines, can be equitably regulated. In short, marine-engine HORSE-POWER requires to be determined and *legalized* as a STANDARD MEASURE of power; and on the same principle that material quantities are regulated by the *standard yard*, and the *standard gallon*, and the *standard pound* weight, so, the motive power employed in steam navigation should be regulated and measured by the *standard marine horse-power*. The standard measure of power being thus determined, it is desirable that the registered power of all steam-vessels should accord therewith; but, whether or not, the same standard should be applied to land-engines is not under present consideration.

SECTION II.

THE RECORDED TEST TRIALS, AND DULY AUTHENTICATED PERFORMANCES OF H.M. STEAM VESSELS "RATTLER," "FAIRY," "ARROGANT," AND "HOGUE," ASSUMED AS THE BASE OF CALCULATIONS, SHOWING THE DIFFERENCES OF STEAM SHIP LOCOMOTIVE PERFORMANCE, WHICH RESULT FROM THE DIFFERENCES OF BUILD, AND OF ENGINE ADAPTATION THERETO, ILLUSTRATED BY TABLES, SHOWING THE MUTUAL RELATION OF DISPLACEMENT, POWER, AND SPEED, IN VESSELS BUILT ON THESE VARIOUS TYPES OF FORM RESPECTIVELY.

In the following tables the horse-power has been calculated according to the standard measure of power thus proposed to be assigned to it, (namely, equivalent to 132·000 lbs., raised at the rate of 1 foot per minute, as expressed by the formula, H.P., $= \frac{\text{P.V.}}{132\cdot000}$,)* and the mutual relations between displacement, speed, and power (H.P.), in each of the four different classes of vessels referred to in the four tables, A, B, C, D, respectively, have been deduced by reference to the well authenticated performance of vessels of the various distinctive classes.

With the view of selecting the best examples of steam-ship performance as the base of these tabular deductions, enquiries as to the performance of merchant steam-vessels

* If this measure H.P. $= \frac{\text{P.V.}}{132\cdot000}$ be adopted as the standard by which the engine-power of steam-vessels is to be registered, it is expected that the registered H.P. of merchant steamers will on the general average be about half of the present nominal power.

have been made; but, it has been found that mercantile records generally have reference to the nominal horse-power of the engines, and not to the working power; or, to the register tonnage of the ship, and not to the ship's displacement; or, whether nautical or statute miles have been the measure of speed is not always stated; or, the rate of speed may not have been corrected according to the disturbing influence of current, tide, and wind; consequently, such records do not furnish the specific data by which the *relative* locomotive performance of steam-ships can be accurately ascertained. The example set by the Admiralty, in publishing and circulating a tabular record of the constructive elements and experimental trials of the screw-ships of the Royal Navy, has not been met, or responded to, by any similar publication on the part of the proprietors of mercantile fleets. That this omission on the part of merchant steam fleet proprietors is injurious to their own interests may be inferred from the great advantages which have resulted to mining interests generally, by reason of the periodical publication of the constructive elements and working operation of Mine pumping engines; and the interests of steam-ship proprietors and of Mine proprietors being analagous as regards the management of their motive power, it can scarcely be doubted that steam-ship efficiency would be greatly promoted by the engineering and ship-building rivalry that would, unquestionably, be consequent on the locomotive DUTY of all steam-ships being ascertained and *numerically* ranked like the Cornish pumping-engines. Notwithstanding, however, the INTERESTS that would be served by such comparisons of steam-ship performance, the published reports of merchant steam-ship trials are generally so deficient of details as regards the ship's *displacement* at time of trial and the

TABLE A.

Showing the mutual relation of Displacement, Power, and Speed, of vessels on the type of RATTLER, *of which vessel the constructive elements are shown in the foregoing Statement, No.* 2, *observing that the H.P. is calculated by the formula, H.P.*, $= \frac{\text{P.V.}}{182\cdot000},$ *and that the Index Number is* 862.

SPEED PER HOUR.		DISPLACEMENT IN TONS.										
Nautical Miles.	Statute Miles.	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
		H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.
6	6·914	25	26	28	30	31	33	34	36	37	38	40
7	8·066	40	42	45	47	50	52	54	57	59	61	63
8	9·218	59	63	67	71	74	78	81	84	88	91	94
9	10·370	84	90	95	100	106	111	115	120	125	129	134
10	11·523	116	123	131	138	145	152	158	165	171	178	184
11	12·675	154	164	174	183	193	202	211	219	228	236	245
12	13·827	200	213	226	238	250	262	274	285	296	307	317
13	14·980	254	271	287	303	318	333	348	362	376	390	403
14	16·123	317	339	359	378	398	416	434	452	470	487	504
15	17·284	391	416	441	465	489	512	534	556	578	599	620
16	18·436	474	505	535	565	593	621	648	675	701	727	753
17	19·589	568	606	642	677	712	745	778	810	841	872	902
18	20·741	675	719	762	804	845	884	923	961	999	1035	1071
19	21·893	794	846	897	946	994	1040	1086	1130	1174	1217	1260
20	23·045	926	987	1046	1103	1158	1213	1266	1319	1369	1420	1469

NOTE.—On the above type. a vessel of 5,000 tons Displacement would be propelled at the rate of 10 nautical miles an hour by 336 horse-power.

TABLE B.

Showing the mutual relation of Displacement, Power, and Speed, of vessels on the type of FAIRY, *of which vessel the constructive elements are shown in the foregoing Statement, No.* 2, *observing that the H. P. is calculated by the formula,* $H.P. = \frac{P.V.}{182{\cdot}000,}$ *and that the Index Number is* 792.

SPEED PER HOUR.		DISPLACEMENT IN TONS.										
Nautical Miles.	Statute Miles.	100	150	200	300	400	500	600	700	800	900	1000
		H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.
6	6·914	6	8	10	12	15	17	19	21	23	25	27
7	8·066	9	12	15	19	23	27	31	34	37	40	43
8	9·218	14	18	22	29	35	41	46	51	56	60	65
9	10·370	20	26	31	41	50	58	66	73	79	86	92
10	11·523	27	36	43	57	69	79	90	100	109	118	127
11	12·675	36	48	58	75	91	106	120	133	145	157	168
12	13·827	47	62	75	98	119	138	155	172	188	204	219
13	14·980	60	78	95	125	151	175	198	219	239	259	278
14	16·123	75	98	119	156	188	219	247	274	299	324	347
15	17·284	92	121	146	191	232	269	304	337	368	398	427
16	18·436	112	146	177	232	281	326	369	408	446	483	518
17	19·589	134	175	212	278	337	391	442	490	535	579	621
18	20·741	159	208	252	331	400	465	525	581	636	688	737
19	21·893	187	245	297	389	471	546	617	684	747	809	868
20	23·045	218	285	346	453	549	637	720	797	872	943	1011

NOTE.—On the above type, a vessel of 5,000 tons Displacement would be propelled at the rate of 10 nautical miles an hour by 370 horse-power.

TABLE C.

Showing the mutual relation of Displacement, Power, and Speed of vessels on the type of Arrogant, *of which vessel the constructive elements are shown in the foregoing Statement, No. 2, observing that the H.P. is calculated by the formula* $H.P. = \frac{P.V.}{132{\cdot}000}$, *and that the Index Number is* 664.

SPEED PER HOUR.		DISPLACEMENT IN TONS.										
Nautical Miles.	Statute Miles.	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
		H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.
6	6·914	52	53	55	56	58	60	61	63	65	66	68
7	8·066	82	85	88	90	93	95	98	100	103	105	108
8	9·218	123	127	131	135	139	142	146	150	153	157	161
9	10·370	175	180	186	192	197	203	208	213	219	224	229
10	11·523	240	247	255	263	271	278	285	293	300	307	314
11	12·675	319	329	340	350	360	370	380	390	399	409	418
12	13·827	414	428	441	454	467	480	493	506	518	530	542
13	14·980	526	544	561	578	594	610	627	643	659	674	690
14	16·123	657	679	701	722	742	763	783	830	823	842	861
15	17·284	809	835	862	888	913	938	963	988	1011	1035	1059
16	18·436	981	1013	1045	1077	1108	1138	1169	1198	1228	1257	1286
17	19·589	1176	1215	1254	1291	1329	1365	1401	1437	1472	1507	1542
18	20·741	1397	1443	1488	1533	1578	1621	1664	1706	1748	1789	1830
19	21·893	1643	1697	1751	1804	1855	1906	1957	2007	2056	2105	2153
20	23·045	1916	1979	2042	2103	2164	2223	2283	2341	2398	2455	2511

Note.—On the above type, a vessel of 5,000 tons Displacement would be propelled at the rate of 10 nautical miles an hour by 441 horse-power.

TABLE D.

Showing the mutual relation of Displacement, Power, and Speed of vessels on the type of HOGUE, *of which vessel the constructive elements are shown in the foregoing Statement, No. 2, observing that the H.P. is calculated by the formula,* $H.P., = \frac{P.V.}{182{\cdot}000}$, *and that the Index Number is* 602.

SPEED PER HOUR.		DISPLACEMENT IN TONS.										
Nautical Miles.	Statute Miles.	3000	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000
		H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.
6	6·914	75	76	78	79	81	83	84	86	87	89	90
7	8·066	118	121	124	126	129	131	134	136	139	141	143
8	9·218	177	181	185	188	192	196	199	203	207	210	214
9	10·370	252	257	263	268	273	279	284	289	295	299	305
10	11·523	345	353	360	368	375	382	390	397	404	411	418
11	12·675	459	470	479	489	499	509	519	528	538	547	557
12	13·827	596	610	623	636	648	661	673	686	698	710	722
13	14·980	758	775	792	808	824	840	856	872	888	903	919
14	16·123	947	968	989	1009	1029	1049	1069	1089	1108	1128	1147
15	17·284	1165	1190	1216	1241	1266	1291	1315	1340	1363	1387	1411
16	18·436	1414	1445	1476	1506	1536	1567	1596	1625	1655	1683	1712
17	19·589	1695	1733	1770	1806	1843	1878	1914	1950	1984	2019	2054
18	20·741	2012	2057	2101	2144	2188	2230	2273	2314	2356	2397	2438
19	21·893	2367	2420	2472	2523	2573	2623	2678	2722	2771	2819	2868
20	23·045	2761	3822	2883	2942	3001	3059	3118	3175	3232	3288	3345

NOTE.—On the above type, a vessel of 5,000 tons Displacement would be propelled at the rate of 10 nautical miles an hour by 485 horse-power.

Referring to the foregoing Tables, A, B, C, D, according to the class of vessel that may be in question, the marine horse-power (H.P.) required to propel a vessel of a given displacement at any required speed from six to twenty nautical miles an hour will be at once determined—for example, a vessel on the type of *Rattler*, of 1,500 tons displacement, to be propelled at the rate of ten nautical miles per hour, will require 152 horse-power. In like manner, the speed corresponding to a given amount of displacement and power, or the required displacement to attain a given speed with a given amount of power will be seen by inspection; also, the theoretical results presented by these Tables can be compared with the actual results of steam-ship trials. Whence, it may be determined in what degree the locomotive performances of different vessels may be respectively superior or inferior to the analagous type of ship on which the Table is based; whereby, the relative merits as regards the locomotive performance of different vessels may be compared, and the cause of difference be enquired into and approximately ascertained.

These Tables may be referred to as indicating the following general principles in connection with Steam Navigation, viz.:—

It may be remarked that the vessels *Rattler*, *Fairy*, *Arrogant*, and *Hogue* are of such different classes that the elements of construction of their immersed bodies embrace the ordinary range of build, whether for packet service or for cargo. In order, therefore, to illustrate the differences of locomotive efficiency, which are incidental to the differences of construction of these four vessels, the notes annexed to the Tables A, B, C, D, may be referred to, by which it appears that vessels of 5,000 tons displacement, and having their immersed bodies constructed on the respective types of

Rattler, *Fairy*, *Arrogant*, and *Hogue*, would respectively be propelled at the rate of ten nautical miles per hour by 336 H.P., 370 H.P., 441 H.P., and 485 H.P., which numbers are in the proportions of 100, 110, 131, and 144, thus affording a general idea of the differences in regard to Power, which would be required, in order that vessels of these different constructions may produce similar results, that is, in order that equal displacement may be propelled at equal speed, and since the immersed bodies of *Arrogant* and *Hogue* are analagous to the general form of ships constructed with a view to sailing properties, we may infer from the above calculations the amount of sacrifice likely to be incurred by applying the screw-propeller to vessels originally built for sailing, instead of building vessels of a form better adapted for mechanical propulsion; or at least, this method of investigation will assist in determining on the mercantile propriety of such conversion of existing stock in comparison with building new ships.

On inspecting the Tables A and B, they will be found to present this remarkable result: namely, that the Table A, on the type of *Rattler*, the length of which ship is under five-and-a-half times the breadth, gives a higher result than Table B, on the type of *Fairy*, the length of which ship is nearly seven times the breadth; for, by Table A, it appears that a vessel of 1,000 tons displacement on the the type of *Rattler* will be propelled at the rate of fifteen nautical miles per hour by 391 horse-power; but, by Table B, on the type of *Fairy*, it will require 427 horse-power to produce the same result, though the elements of construction, on which Table B is based, are, as regards the ratio of length to breadth, much more analagous than those of Table A to the elements now generally received by steam-ship constructors as most conducive to speed. In fact, the locomotive

performance of H.M. screw-ship *Rattler* has, hitherto, been found superior to that of any other screw vessel, whether in the Royal Navy or in the merchant service, with which comparison has been instituted, as shown by its giving the highest index number of locomotive performance, when tested by the formula referred to; but, having now held this pre-eminent position for twelve years (for, *Rattler* was designed in "1841,") it is, of course, to be expected that amongst the multiplicity of rivals of modern construction, and the confident pretensions to superiority advanced successively in favor of each ship of the most recent build, the *Rattler* must soon assume a secondary place: until, however, such superiority shall be realized the *Rattler* may be regarded as a type of form and of engine adaptation thereto worthy of the study of steam-ship constructors * and the attention of steam-ship proprietors; accordingly, a further Table, E, has been prepared, which we may call the Key Table for vessels on the type of *Rattler*, extending the range of displacement to dimensions which exceed the greatest displacement of mercantile shipping hitherto built, thus affording the means of comparison with modern ships, and also a test of the progressive advancement of modern science and art in the important work of steam-ship construction as exemplified by a progressively improving scale of commercial efficiency.

* In an Essay on "Marine Engine Classification," published by Weale, London, Mr. Atherton has endeavoured to ascertain, from a comparison of RATTLER with other screw-ships, what *principles* of engine construction have conduced to the best results; and it is worthy of remark that the effective power of RATTLER, as tested at the Dynamometer at Woolwich, 29th September, 1851, was found to be 84 per cent. of the gross indicated power, being a higher per centage of effective power than is known to have been attained by any *paddle-wheel* vessel.

TABLE E.

Showing the Mutual Relation of DISPLACEMENT, POWER, and SPEED, for Vessels on the type of RATTLER.

Index Number 862, and H.P $= \frac{\text{P.V.}}{182{\cdot}000}$.

SPEED PER HOUR.	DISPLACEMENT IN TONS.																				
N. MILES.	250	50	750	1000	125 0	1500	1750	2000	2250	2500	2750	3000	3500	4000	4500	5000	6000	7000	8000	9000	10000
	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H. P.
6	10	16	20	25	29	33	36	40	43	46	49	52	58	64	68	73	83	91	100	108	116
7	16	25	32	40	46	52	58	63	68	73	78	83	92	100	108	115	131	145	159	172	184
8	24	37	49	59	69	78	86	94	102	109	116	123	137	148	162	172	196	217	237	256	276
9	33	53	70	84	97	111	122	134	145	155	166	175	194	212	229	245	279	309	338	365	388
10	46	73	96	116	134	152	168	184	199	213	227	241	267	292	316	336	383	423	463	501	536
11	61	97	127	154	178	202	223	245	265	284	302	320	355	388	419	448	510	564	616	667	712
12	79	126	165	200	232	262	290	317	343	368	392	416	461	504	545	581	660	732	800	865	928
13	101	160	210	254	295	333	369	403	437	468	499	529	586	640	693	739	840	931	1017	1100	1180
14	126	200	262	317	368	416	461	504	545	585	623	661	732	800	865	923	1049	1162	1270	1374	1472
15	155	246	322	390	453	512	567	620	671	720	767	813	901	984	1064	1135	1291	1429	1562	1690	1812
16	188	299	391	474	550	621	688	753	814	873	931	987	1093	1196	1292	1377	1567	1735	1897	2051	2200
17	226	358	469	568	659	745	825	902	976	1047	1116	1183	1310	1432	1549	1652	1878	2080	2274	2460	2636
18	268	425	557	675	783	884	980	1071	1159	1243	1324	1405	1556	1700	1839	1961	2230	2470	2700	2921	3132
19	315	500	655	794	921	1040	1152	1260	1363	1462	1558	1652	1830	2000	2163	2307	2623	2905	3176	3435	3684
20	367	583	765	926	1074	1213	1344	1469	1590	1705	1817	1927	2134	2333	2523	2690	3059	3388	3704	4007	4296

TABLE F.

As ships are generally spoken of with reference to their Tonnage (Builder's Measurement) and not with reference to their Displacement, the following Table shows the mutual relation of TONNAGE *(old rule,)* DISPLACEMENT *in tons, and the corresponding length, breadth, and mean draught of ships constructed on the proportions of* RATTLER.

DISPLACEMENT IN TONS	250	500	750	1000	1250	1500	2000	2500	3000	4000	5000	6000	8000	10000
	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.
DIMENSIONS PROPORTIONAL TO RATTLER. — LENGTH (L)	108·5	136·7	156·5	172·2	185·5	197·1	216·11	233·7	248·3	273·3	294·4	312·9	344·3	370·10
BREADTH (B)	20·1	25·4	29·0	31·11	34·4½	36·6¼	40·2¼	43·3½	46·0	50·7½	54·6½	57·11½	63·9½	68·8¾
MEAN DRAUGHT (D)	8·3½	10·5½	11·11½	13·2	14·2¼	15·1	16·7	17·10½	19·0	20·11	22·6¼	23·11	26·4	28·4½
TONNAGE (OLD MEASUREMENT)	207	414	621	828	1035	1242	1656	2070	2484	3312	4140	4969	6625	8281

From the foregoing Table, E, it appears that the power required to propel steam-ships of similar build at a given speed does not increase in the same proportion as the size or tonnage of the ships, for, by inspecting the Table we observe, that if a ship of 500 ton's displacement be propelled at the rate of fourteen nautical miles per hour by 200-horse power, a ship on the same type of build, but of 4000 tons, being *eight times the displacement*, will be propelled at the same rate of speed by 800-horse power, being only *four times the power*. It appears also that a considerable decrease of displacement, consequent on the decreased immersion of the same ship, by reason, for instance, of the consumption of fuel during a long passage, will, if the same power be exerted, be attended with but a comparatively small increase of speed, for example, if 3000 ton's displacement (see Table E) be propelled at the rate of ten nautical miles an hour by 241 horse-power, the reduction of displacement to 2000 tons, caused by the consumption of 1000 tons of fuel, being a reduction of *one third*, will, with about the same horse-power (viz., 245 H.P.,) be attended with an acceleration of speed to eleven nautical miles, being an increase of *one tenth* only, supposing the operation of the screw to be equally effective when working at its reduced immersion. Hence, if the working power during a long passage be constant, the speed of the vessel, when at the *mean displacement*, will give very nearly the average speed of the passage under steam; accordingly, the following Tables, illustrating the CAPABILITIES of steam ships, have been calculated with reference to the *mean displacement* consequent on the gradual consumption of coal during the passage.

SECTION III.

TABLES INTENDED TO SHOW THE CAPABILITIES OF STEAM-SHIPS ON THE TYPE OF H.M.S. "RATTLER," FROM FIVE HUNDRED TO TEN THOUSAND TON'S DISPLACEMENT, EMBRACING THE MUTUAL RELATION OF DISPLACEMENT, POWER, SPEED, WEIGHT OF HULL AND EQUIPMENT, COALS, FREIGHT, TIME THE COALS WILL LAST, AND THE DISTANCE CAPABLE OF BEING TRAVERSED WITHOUT RE-COALING; WITH DEDUCTIONS, SHOWING THE PROGRESSIVELY INCREASING DIFFICULTIES WHICH ATTEND THE REALISATION OF INCREASING SPEED.

IN illustration of the further application of the foregoing Tables to the solution of enquiries as to the CAPABILITIES of steam ships, the following SERIES, Nos. 1 to 13 inclusive have been constructed as TABLES OF REFERENCE for ascertaining, approximately, the CAPABILITIES of ships of various sizes, for example :—500 Tons mean Displacement 750, 1000, 1250, 1500, 2000, 2500, 3000, 4000, 5000, 6000, 8000, and 10,000 tons. This series of calculations has been based on the assumption that the vessels shall have been constructed, both as regards the hull and the adaptation of machinery thereto, on elements capable of realising a degree of locomotive performance not inferior to that attained by H.M. screw steam-vessel *Rattler*, as indicated by the index number deduced from the formula $\frac{V^3 \times D^{\frac{2}{3}}}{H.P.}$ being not less than 862, in which formula H.P. $= \frac{P.V.}{132 \cdot 000,}$ the unit of power being thus assumed at 132·000 lbs. raised one foot per minute,

agreeably to the engineering practice, which has been realised in H.M. packets before referred to. These Tables present a system of investigation, whereby steam-ship proprietors may approximately determine whether or not a Stock vessel, proposed for any contemplated service, may be expected to meet the requirements of the service in regard to distance to be steamed without re-coaling, time of passage, and amount of displacement available for passengers and cargo, also to aid them, in the case of building new ships, in originally fixing upon such a size and class of ship, and such an amount of engine-power in proportion to the ship's displacement, as may be most suitable for the specific object in view, observing, that in these Tables, the weight of the ship's hull and equipment ready for sea, exclusive of engines, coals, and cargo, is taken at 40 per cent. of the mean displacement; the weight of the engines and boilers complete is taken at one ton per H.P., and the consumption of fuel at four cwt. per H.P. per day of twenty-four hours;* also, the favorable and adverse influences of wind and current are supposed, on the average, to balance.

* The weight of the Hull and Equipment, with reference to the mean displacement, will be materially dependant on the build of the ship; and the unit of H.P. having been taken at 132·000 lbs. raised one foot per minute (which is about double the ordinary average commercial unit of nominal H.P.), the assumed weight of one ton per H.P. for the engines, and four cwt. per H.P. per day for the consumption of fuel, is nearly in accordance with the best realised practice of the present day. The saving of weight which will, doubtless, be effected by improvements in ship, engine, and boiler construction, will increase the proportion of displacement, available for freight, above the limit calculated upon in the Tables, which have been based on data already realised.

SERIES 1.—TABLE No. 1.

Calculated for the mean DISPLACEMENT *of* 500 TONS. *Index Number* 862, *and H.P.* = $\frac{\text{P.V.}}{182\cdot000}$.

SPEED—PER HOUR.	HORSE-POWER.	WEIGHT OF HULL AND ENGINES.	COAL. 25 TONS.			COAL. 50 TONS.			COAL. 100 TONS.			COAL. 150 TONS.			COAL. 200 TONS.		
			Available for Freight.	Steaming time	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.
N. M.	H. P.	TONS.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.
6	16	216	271	7·19	1125	259	15·15	2250	234	31. 6	4500	209	46·21	6750	184	62·12	9000
7	25	225	262	5· 0	840	250	10· 0	1680	225	20· 0	3360	200	30· 0	5040	175	40· 0	6720
8	37	237	250	3· 9	649	238	6·18	1298	213	13·12	2596	188	20· 6	3894	163	27· 1	5192
9	53	253	234	2· 9	509	222	4·17	1019	197	9·10	2038	172	14· 3	3057	147	18·21	4077
10	73	273	214	1·17	411	202	3·10	822	177	6·20	1645	152	10· 6	2467	127	13·17	3290
11	97	297	190	1· 7	339	178	2·13	679	153	5· 3	1358	128	7·17	2037	103	10· 7	2717
12	126	326	161	1· 0	288	149	2· 0	576	124	4· 0	1152	99	6· 0	1728	74	8· 0	2304
13	160	360	127	0·19	243	115	1·14	487	90	3· 3	975	65	4·16	1462	40	6· 6	1950
14	200	400	87	0·15	210	75	1· 6	420	50	2·12	840	25	3·18	1260	0		
15	246	446	41	0·12	180	29	1· 0	360	4	2· 0	720	0					
16	299	499	0														
17	358	558															
18	425	625															
19	500	700															
20	583	783															

SERIES 1.—TABLE No. 2.

Calculated for the mean DISPLACEMENT *of* 750 TONS. *Index Number* 862, *and H.P.* $= \frac{\text{P.V.}}{182{\cdot}000}$.

SPEED—PER HOUR.	HORSE-POWER.	WEIGHT OF HULL AND ENGINES.	COAL. 37½ TONS.			COAL. 75 TONS.			COAL. 150 TONS.			COAL. 225 TONS.			COAL. 300 TONS.		
			Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.
N. M.	H. P.	TONS.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.
6	20	320	411	9· 9	1350	392	18·18	2700	355	37·12	5400	317	56· 6	8100	280	75· 0	10800
7	32	332	399	5·21	984	380	11·17	1969	343	23·10	3937	305	35· 3	5906	268	46·21	7875
8	49	349	382	3·20	735	363	7·16	1470	326	15· 7	2940	288	22·23	4410	251	30·15	5880
9	70	370	361	2·16	578	342	5· 8	1156	305	10·17	2313	267	16· 1	3469	230	21·10	4626
10	96	396	335	1·23	469	316	3·22	937	279	7·19	1875	241	11·17	2812	204	15·15	3750
11	127	427	304	1·11	389	285	2·23	778	248	5·22	1556	210	8·20	2335	173	11·19	3113
12	165	465	266	1· 3	327	247	2· 6	654	210	4·13	1308	172	6·19	1962	135	9· 2	2616
13	210	510	221	0·21	278	202	1·19	556	165	3·13	1111	127	5· 8	1667	90	7· 3	2223
14	262	562	169	0·17	240	150	1·10	479	113	2·20	959	75	4· 6	1438	38	5·17	1918
15	322	622	109	0·14	210	90	1· 4	420	53	2· 8	840	15	3·12	1260	0		
16	391	691	40	0·12	192	21	0·23	368	0								
17	469	769	0														
18	557	857															
19	655	955															
20	765	1065															

SERIES 1.—TABLE No. 3.

Calculated for the mean DISPLACEMENT *of* 1000 TONS. *Index Number* 862, *and H.P.* $= \frac{P.V.}{182 \cdot 000}$.

SPEED—PER HOUR	HORSE-POWER.	WEIGHT OF HULL AND ENGINES.	COAL. 50 TONS.			COAL. 100 TONS.			COAL. 200 TONS.			COAL. 300 TONS.			COAL. 400 TONS.		
			Available for Freight.	Steaming time	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.
N. M.	H. P.	TONS.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.
6	25	425	550	10· 0	1440	525	20· 0	2880	475	40· 0	5760	425	60· 0	8640	375	80· 0	11520
7	40	440	535	6· 6	1050	510	12·12	2100	460	25· 0	4200	410	37·12	6300	360	50· 0	8400
8	59	459	516	4· 6	814	491	8·11	1628	441	16·23	3256	391	25·10	4882	341	33·22	6512
9	84	484	491	2·23	642	466	5·23	1285	416	11·21	2569	366	17·21	3857	316	23·19	5139
10	116	516	459	2· 4	517	434	4· 7	1035	384	8·15	2070	334	12·22	3103	284	17· 6	4140
11	154	554	421	1·15	429	396	3· 6	858	346	6·12	1716	296	9·18	2574	246	13· 0	3432
12	200	600	375	1· 6	360	350	2·12	720	300	5· 0	1440	250	7·12	2160	200	10· 0	2880
13	254	654	321	1· 0	307	296	1·23	614	246	3·22	1228	196	5·22	1843	146	7·21	2457
14	317	717	258	0·19	264	233	1·14	528	183	3· 3	1057	133	4·18	1590	83	6· 7	2114
15	390	790	185	0·15	231	160	1· 7	461	110	2·13	922	60	3·20	1385	10	5· 3	1845
16	474	874	101	0·13	202	76	1· 1	404	26	2· 2	808	0					
17	568	968	7	0·11	178	0	0·21	357	0								
18	675	1075	0														
19	794	1194															
20	926	1326															

SERIES 1.—TABLE No. 4.

Calculated for the menn DISPLACEMENT *of* 1250 TONS. *Index Number* 862, *and H.P.* $= \frac{P.V.}{132 \cdot 000}$.

SPEED—PER HOUR.	HORSE-POWER.	WEIGHT OF HULL AND ENGINES.	COAL. 62½ TONS.			COAL. 125 TONS.			COAL. 250 TONS.			COAL. 375 TONS.			COAL. 500 TONS.		
			Available for Freight.	Steaming time.	Steaming distance.	Availbale for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.
N. M.	H. P.	TONS.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.
6	29	529	690	10·19	1552	658	21·13	3103	596	43· 2	6207	533	64·15	9310	471	86· 5	12414
7	46	546	673	6·19	1141	641	13·14	2282	579	27· 4	4564	516	40·18	6846	454	54. 8	9128
8	69	569	650	4·13	869	618	9· 1	1739	556	18· 3	3478	493	27· 4	5217	431	36· 6	6956
9	97	597	622	3· 5	696	590	6·11	1391	528	12·21	2783	465	19· 8	4174	403	25·19	5566
10	134	634	585	2· 8	560	553	4·16	1119	491	9· 8	2238	428	14· 0	3357	366	18·16	4477
11	178	678	541	1·18	463	509	3·12	927	447	7· 0	1853	384	10·12	2780	322	14· 1	3707
12	232	732	487	1· 8	388	455	2·17	776	393	5· 9	1552	330	8· 2	2328	268	10·19	3104
13	295	795	424	1· 1	330	392	2· 3	661	330	4· 6	1321	267	6· 8	1982	205	8·11	2643
14	368	868	351	0·20	285	319	1·17	570	257	3· 9	1141	194	5· 2	1711	132	6·19	2282
15	453	953	266	0·17	248	234	1· 9	497	172	2·18	993	109	4· 3	1490	47	5·12	1987
16	550	1050	169	0·14	218	137	1· 3	436	75	2· 6	872	12	3· 9	1308	0		
17	659	1159	60	0·11	193	28	0·23	387	0								
18	783	1283	0														
19	921	1421															
20	1074	1574															

SERIES 1.—TABLE No. 5.

Calculated for the mean DISPLACEMENT *of* 1500 TONS. *Index Number* 862, *and H.P.* = $\frac{\text{H.P.}}{132{\cdot}000}$

SPEED—PER HOUR.	HORSE-POWER.	WEIGHT OF HULL AND ENGINES.	COAL. 75 TONS.			COAL. 150 TONS.			COAL. 300 TONS.			COAL. 450 TONS.			COAL. 600 TONS.		
			Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.
N. M.	H. P.	TONS.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D.H.	N. M.	TONS.	D. H.	N. M.
6	33	633	829	11· 9	1636	792	22·17	3273	717	45·11	6546	642	68· 4	9819	567	90·22	13092
7	52	652	810	7· 5	1211	773	14·10	2423	698	28·20	4845	623	43· 6	7268	548	57·16	9691
8	78	678	784	4·19	923	747	9·15	1846	672	19· 5	3692	597	28·20	5538	522	38·11	7384
9	111	711	751	3· 9	730	714	6·18	1459	639	13·12	2919	564	20· 6	4378	489	27· 1	5838
10	152	752	710	2·11	592	673	4·22	1184	598	9·21	2368	523	14·19	3552	448	19 18	4737
11	202	802	660	1·21	490	623	3·17	980	548	7·10	1960	473	11· 3	2940	398	14·20	3921
12	262	862	600	1·10	412	563	2·21	824	488	5·17	1649	413	8·14	2473	338	11·11	3298
13	333	933	529	1· 3	351	492	2· 6	703	417	4·12	1405	342	6·18	2108	267	9· 0	2811
14	416	1016	446	0·22	302	409	1·19	606	334	3·15	1211	259	5·10	1817	184	7· 5	2423
15	512	1112	350	0·18	264	313	1·11	527	238	2·22	1054	163	4· 9	1581	88	5·21	2109
16	621	1221	241	0·14	232	204	1· 5	464	129	2·10	927	54	3·15	1391	0		
17	745	1345	117	0·12	205	80	1· 0	411	5	2· 0	821	0					
18	884	1484	0														
19	1040	1640															
20	1213	1813															

SERIES 1.—TABLE No. 6.

Calculated for the mean DISPLACEMENT *of* 2000 TONS. *Index Number* 862, *and H.P.* $= \frac{P.V.}{182\cdot000}$.

SPEED—PER HOUR.	HORSE-POWER.	WEIGHT OF HULL AND ENGINES.	COAL. 100 TONS.			COAL. 200 TONS.			COAL. 400 TONS.			COAL. 600 TONS.			COAL. 800 TONS.		
			Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.
N. M.	H. P.	TONS.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D.H.	N. M.	TONS.	D. H.	N. M.
6	40	840	1110	12·12	1800	1060	25· 0	3600	960	50· 0	7200	860	75· 0	10800	760	100· 0	14400
7	63	863	1087	7·22	1333	1037	15·21	2667	937	31·18	5334	837	47·15	8001	737	63·12	10668
8	94	894	1056	5· 8	1021	1006	10·15	2042	906	21· 7	4085	806	31·22	6127	706	42·13	8170
9	134	934	1016	3·18	806	966	7·11	1612	866	14·22	3224	766	22· 9	4836	666	29·20	6448
10	184	984	966	2·17	652	916	5·10	1304	816	10·21	2608	716	16· 7	3912	616	21·18	5217
11	245	1045	905	2· 1	539	855	4· 2	1078	755	8· 4	2156	655	12· 6	3234	555	16· 8	4312
12	317	1117	833	1·14	454	783	3· 4	909	683	6· 7	1818	583	9·11	2727	483	12·15	3636
13	403	1203	747	1· 6	387	697	2·11	773	597	4·23	1547	497	7·10	2320	397	9·22	3094
14	504	1304	646	1· 0	333	596	2· 0	667	496	3·23	1333	396	5·22	2000	296	7·22	2667
15	620	1420	530	0·19	291	480	1·15	581	380	3· 5	1162	280	4·20	1743	180	6·11	2325
16	753	1553	397	0·16	255	347	1· 8	510	247	2·16	1020	147	3·23	1530	47	5· 7	2040
17	902	1702	248	0·13	226	198	1· 3	452	98	2· 5	904	0					
18	1071	1871	79	0·11	202	29	0·22	403	0								
19	1260	2060	0														
20	1469	2269															

SERIES 1.—TABLE No. 7.

Calculated for the mean DISPLACEMENT *of* 2500 TONS. *Index Number* 862, *and H.P.* = $\frac{\text{P.V.}}{132{\cdot}000}$.

SPEED—PER HOUR.	HORSE-POWER.	WEIGHT OF HULL AND ENGINES.	COAL. 125 TONS.			COAL. 250 TONS.			COAL. 500 TONS.			COAL. 750 TONS.			COAL. 1000 TONS.		
			Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.
N. M.	H. P.	TONS.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.
6	46	1046	1391	13·14	1956	1329	27· 4	3913	1204	54· 8	7826	1079	81·12	11739	954	108·17	15652
7	73	1073	1364	8·13	1438	1302	17· 3	2877	1177	34· 6	5753	1052	51· 9	8630	927	68·12	11507
8	109	1109	1328	5·18	1101	1266	11·11	2202	1141	22·22	4403	1016	34· 9	6605	891	45·21	8807
9	155	1155	1282	4· 1	871	1220	8· 2	1742	1095	16· 3	3484	970	24· 4	5226	845	32· 6	6968
10	213	1213	1224	2·22	704	1162	5·21	1408	1037	11·18	2816	912	17·14	4224	787	23·11	5633
11	284	1284	1153	2· 5	581	1091	4·10	1162	966	8·19	2324	841	13· 5	3486	716	17·15	4648
12	368	1368	1069	1·17	489	1007	3·10	978	882	6·19	1956	757	10· 4	2934	632	13·14	3913
13	468	1468	969	1· 8	417	907	2·16	833	782	5· 8	1666	657	8· 0	2500	532	10·16	3333
14	585	1585	852	1· 2	359	790	2· 3	718	665	4· 7	1436	540	6·10	2154	415	8·13	2872
15	720	1720	717	0·21	312	655	1·18	625	530	3·11	1250	405	5· 5	1875	280	6·23	2500
16	873	1873	564	0·17	275	502	1·10	550	377	2·21	1099	252	4· 7	1649	127	5·17	2199
17	1047	2047	390	0·14	243	328	1· 5	487	203	2· 9	974	78	3·14	1461	0		
18	1243	2243	186	0·12	217	124	1· 0	434	0								
19	1462	2462	0														
20	1705	2705															

SERIES 1.—TABLE No. 8.

Calculated for the mean DISPLACEMENT *of* 3000 TONS. *Index Number* 862, *and H.P.* $= \frac{\text{P.V.}}{132{\cdot}000}$.

SPEED—PER HOUR.	HORSE-POWER.	WEIGHT OF HULL AND ENGINES.	COAL. 150 TONS.			COAL. 300 TONS.			COAL. 600 TONS.			COAL. 900 TONS.			COAL. 1200 TONS.		
			Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.
N. M.	H. P.	TONS.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.
6	52	1252	1673	14·10	2077	1598	28·20	4154	1448	57·17	8307	1298	86·13	12461	1148	115· 9	16615
7	83	1283	1642	9· 1	1518	1567	18· 2	3036	1417	36· 3	6072	1267	54· 5	9109	1117	72· 7	12145
8	123	1323	1602	6· 2	1170	1527	12· 5	2341	1377	24· 9	4681	1227	36·14	7022	1077	48·19	9363
9	175	1375	1550	4· 7	926	1475	8·14	1852	1325	17· 3	3703	1175	25·17	5555	1025	34· 7	7407
10	241	1441	1484	3· 3	747	1409	6· 5	1494	1259	12·11	2987	1109	18·16	4481	959	24·21	5975
11	320	1520	1405	2· 8	619	1330	4·16	1237	1180	9· 9	2475	1030	14· 1	3712	880	18·18	4950
12	416	1616	1309	1·19	519	1234	3·15	1038	1084	7· 5	2077	934	10·19	3115	784	14·10	4154
13	529	1729	1196	1·10	443	1121	2·20	885	971	5·16	1770	821	8·12	2656	671	11· 8	3541
14	661	1861	1064	1· 3	381	989	2· 6	762	839	4·13	1525	689	6·19	2287	539	9· 2	3050
15	813	2013	912	0·22	332	837	1·20	664	687	3·17	1328	537	5·13	1993	387	7· 9	2657
16	987	2187	738	0·18	292	663	1·12	583	513	3· 1	1167	363	4·13	1750	213	6· 2	2334
17	1183	2383	542	0·15	259	467	1· 6	517	317	2·13	1034	167	3·19	1552	17	5· 2	2069
18	1405	2605	320	0·13	232	245	1· 2	461	95	2· 3	922	0					
19	1652	2852	73	0·11	207	0											
20	1927	3127	0														

SERIES 1.—TABLE No. 9.

Calculated for the mean DISPLACEMENT *of* 4000 TONS. *Index Number* 862, *and H.P.* = $\frac{\text{P.V.}}{182 \cdot 000}$.

SPEED—PER HOUR.	HORSE-POWER.	WEIGHT OF HULL AND ENGINES.	COAL. 200 TONS.			COAL. 400 TONS.			COAL. 800 TONS.			COAL. 1200 TONS.			COAL. 1600 TONS.		
			Available for Freight.	Steaming time	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.
N. M.	H. P.	TONS.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.
6	64	1664	2236	15·15	2250	2136	31· 6	4500	1936	62·12	9000	1736	93·18	13500	1536	125· 0	18000
7	100	1700	2200	10· 0	1680	2100	20· 0	3360	1900	40· 0	6720	1700	60· 0	10080	1500	80· 0	13440
8	148	1748	2152	6·18	1297	2052	13·12	2595	1852	27· 1	5189	1652	40·13	7784	1452	54· 1	10379
9	212	1812	2088	4·17	1019	1988	9·10	2038	1788	18·21	4075	1588	28· 7	6113	1388	37·18	8151
10	292	1892	2008	3·10	822	1908	6·20	1644	1708	13·17	3287	1508	20·13	4931	1308	27· 9	6575
11	388	1988	1912	2·14	680	1812	5· 4	1361	1612	10· 7	2721	1412	15·11	4082	1212	20·15	5443
12	504	2104	1796	2· 0	571	1696	3·23	1143	1496	7.22	2286	1296	11·21	3429	1096	15·21	4572
13	640	2240	1660	1·13	487	1560	3· 3	975	1360	6· 6	1950	1160	9· 9	2925	960	12·12	3900
14	800	2400	1500	1· 6	420	1400	2·12	840	1200	5· 0	1680	1000	7·12	2520	800	10· 0	3360
15	984	2584	1316	1· 0	366	1216	2· 1	732	1016	4· 2	1463	816	6· 2	2195	616	8· 3	2927
16	1196	2796	1104	0·20	321	1004	1·16	642	804	3· 8	1284	604	5· 0	1926	404	6·17	2569
17	1432	3032	868	0·17	285	768	1·10	570	568	2·19	1139	368	4· 4	1709	168	5·14	2279
18	1700	3300	600	0·14	254	500	1· 4	508	300	2· 8	1017	100	3·12	1525	0		
19	2000	3600	300	0·12	228	200	1· 0	456	0								
20	2333	3933	0														

SERIES 1.—TABLE No. 10.

Calculated for the mean Displacement *of* 5000 Tons. *Index Number* 862, *and H.P.* $= \frac{P.V.}{182 \cdot 000}$.

Speed—per hour.	Horse-power.	Weight of Hull and Engines.	Coal. 250 Tons.			Coal. 500 Tons.			Coal. 1000 Tons.			Coal. 1500 Tons.			Coal. 2000 Tons.		
			Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.
N. M.	H. P.	Tons.	Tons.	D. H.	N. M.	Tons.	D. H.	N. M.	Tons.	D. H.	N. M.	Tons.	D.H.	N. M.	Tons.	D. H.	N. M.
6	73	2073	2802	17· 3	2466	2677	34· 6	4931	2427	68·12	9863	2177	102·18	14794	1927	137· 0	19726
7	115	2115	2760	10·21	1826	2635	21·18	3652	2385	43·11	7304	2135	65· 5	10956	1885	86·23	14609
8	172	2172	2703	7· 6	1395	2578	14·13	2791	2328	29· 2	5581	2078	43·14	8372	1828	58· 3	11163
9	245	2245	2630	5· 2	1102	2505	10· 5	2204	2255	20·10	4408	2005	30·15	6612	1755	40·20	8816
10	336	2336	2539	3·17	893	2414	7·11	1786	2164	14·21	3571	1914	22· 7	5357	1664	29·18	7143
11	448	2448	2427	2·19	737	2302	5·14	1473	2052	11· 4	2946	1802	16·18	4419	1552	22· 8	5893
12	581	2581	2294	2· 4	619	2169	4· 7	1239	1919	8·14	2478	1669	12·21	3717	1419	17· 5	4957
13	739	2739	2136	1·17	528	2011	3· 9	1055	1761	6·18	2111	1511	10· 3	3166	1261	13·13	4222
14	923	2923	1952	1· 8	455	1827	2·17	910	1577	5·10	1820	1327	8· 3	2730	1077	10·20	3640
15	1135	3135	1740	1. 2	396	1615	2· 5	793	1365	4.10	1586	1115	6·14	2379	865	8·19	3172
16	1377	3377	1498	0·22	349	1373	1·20	697	1123	3·15	1394	873	5·10	2091	623	7· 6	2789
17	1652	3652	1223	0·18	309	1098	1·12	617	848	3· 1	1234	598	4·13	1851	348	6· 1	2469
18	1961	3961	914	0·15	275	789	1· 7	550	539	2·13	1101	289	3·19	1651	39	5· 2	2202
19	2307	4307	568	0·13	247	443	1· 2	494	193	2· 4	988	0					
20	2690	4690	185	0·11	223	60	0·22	446	0								

SERIES 1.—TABLE No. 11.

Calculated for the mean DISPLACEMENT *of* 6000 TONS. *Index Number* 862, *and* $H.P. = \frac{P.V.}{182 \cdot 000}$.

SPEED—PER HOUR.	HORSE-POWER.	WEIGHT OF HULL AND ENGINES.	COAL. 300 TONS.			COAL. 600 TONS.			COAL. 1200 TONS.			COAL. 1800 TONS.			COAL. 2400 TONS.		
			Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.
N. M.	H. P.	TONS.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.
6	83	2483	3367	18·2	2602	3217	36·3	5205	2917	72·7	10409	2617	108·10	15614	2317	144·14	20819
7	131	2531	3319	11·11	1924	3169	22·22	3847	2869	45·19	7694	2569	68·16	11543	2269	91·14	15389
8	196	2596	3254	7·16	1469	3104	15·7	2939	2804	30·15	5877	2504	45·22	8816	2204	61·5	11755
9	279	2679	3171	5·9	1161	3021	10·18	2322	2721	21·12	4645	2421	32·6	6967	2121	43·0	9290
10	383	2783	3067	3·22	940	2917	7·20	1880	2617	15·16	3760	2317	23·12	5640	2017	31·8	7520
11	510	2910	2940	2·23	776	2790	5·21	1553	2490	11·18	3105	2190	17·15	4658	1890	23·13	6211
12	660	3060	2790	2·7	654	2640	4·13	1309	2340	9·2	2618	2040	13·15	3927	1740	18·4	5236
13	840	3240	2610	1·19	557	2460	3·14	1114	2160	7·3	2228	1860	10·17	3342	1560	14·7	4457
14	1049	3449	2401	1·10	480	2251	2·21	961	1951	5·17	1922	1651	8·14	2883	1351	11·11	3844
15	1291	3691	2159	1·4	418	2009	2·8	836	1709	4·16	1673	1409	6·23	2509	1109	9·7	3346
16	1567	3967	1883	0·23	368	1733	1·22	735	1433	3·20	1470	1133	5·18	2205	833	7·16	2941
17	1878	4278	1572	0·19	326	1422	1·14	652	1122	3·5	1303	822	4·19	1955	522	6·9	2607
18	2230	4630	1220	0·16	291	1070	1·8	581	770	2·17	1162	470	4·1	1743	170	5·9	2325
19	2623	5023	827	0·14	260	677	1·3	521	377	2·7	1042	77	3·10	1563	0		
20	3059	5459	391	0·12	235	241	1·0	471	0								

SERIES 1.—TABLE No. 12.

Calculated for the mean DISPLACEMENT *of* 8000 TONS. *Index Number* 862, *and H.P.* $= \frac{P.V.}{132\cdot000}$.

SPEED—PER HOUR.	HORSE-POWER.	WEIGHT OF HULL AND ENGINES.	COAL. 400 TONS.			COAL. 800 TONS.			COAL. 1600 TONS.			COAL. 2400 TONS.			COAL. 3200 TONS.		
			Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.	Available for Freight.	Steaming time.	Steaming distance.
N. M.	H. P.	TONS.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.
6	100	3300	4500	20· 0	2880	4300	40· 0	5760	3900	80· 0	11520	3500	120· 0	17280	3100	160· 0	23040
7	159	3359	4441	12·14	2113	4241	25· 4	4226	3841	50· 8	8453	3441	75·11	12679	3041	100·15	16906
8	237	3437	4363	8·11	1620	4163	16·21	3240	3763	33·18	6481	3363	50·15	9721	2963	67·12	12962
9	338	3538	4262	5·22	1278	4062	11·20	2556	3662	23·16	5112	3262	35·12	7669	2862	47· 8	10225
10	463	3663	4137	4· 8	1037	3937	8·15	2073	3537	17· 7	4147	3137	25·22	6220	2737	34·13	8294
11	616	3816	3984	3· 6	857	3784	6·12	1714	3384	13· 0	3428	2984	19·11	5142	2584	25·23	6856
12	800	4000	3800	2·12	720	3600	5· 0	1440	3200	10· 0	2880	2800	15· 0	4320	2400	20· 0	5760
13	1017	4217	3583	1·23	613	3383	3·22	1227	2983	7·21	2453	2583	11·19	3680	2183	15·17	4907
14	1270	4470	3330	1·14	529	3130	3· 4	1058	2730	6· 7	2116	2330	9·10	3175	1930	12·14	4233
15	1562	4762	3038	1· 7	461	2838	2·13	922	2438	5· 3	1843	2038	7·16	2765	1638	10· 6	3687
16	1897	5097	2703	1· 1	405	2503	2· 3	810	2103	4· 5	1619	1703	6· 7	2429	1303	8·10	3239
17	2274	5474	2326	0·21	359	2126	1·18	718	1726	3·12	1435	1326	5· 6	2153	926	7· 1	2871
18	2700	5900	1900	0·18	320	1700	1·12	640	1300	2·23	1280	900	5·10	1920	500	5·22	2560
19	3176	6376	1424	0·15	287	1224	1· 6	574	824	2·12	1148	424	3·18	1723	24	5· 1	2297
20	3704	6904	896	0·13	259	696	1· 2	518	296	2· 4	1037	0					

SERIES 1.—TABLE No. 13.

Calculated for the mean DISPLACEMENT *of* 10,000 TONS. *Index Number* 862, *and H.P.* = $\frac{\text{P.V.}}{182\cdot000}$.

SPEED—PER HOUR.	HORSE-POWER.	WEIGHT OF HULL AND ENGINES.	COAL. 500 TONS. Available for Freight.	Steaming time	Steaming distance.	COAL. 1000 TONS. Available for Freight.	Steaming time.	Steaming distance.	COAL. 2000 TONS. Available for Freight.	Steaming time.	Steaming distance.	COAL. 3000 TONS. Available for Freight.	Steaming time.	Steaming distance.	COAL. 4000 TONS. Available for Freight.	Steaming time.	Steaming distance.
N. M.	H. P.	TONS.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.
6	116	4116	5634	21·13	3103	5384	43· 2	6207	4884	86· 5	12414	4384	129· 7	18621	3884	172·10	24828
7	184	4184	5566	13·14	2283	5316	27· 4	4565	4816	54· 8	9130	4316	81·12	13695	3816	108·17	18261
8	276	4276	5474	9· 1	1739	5224	18· 3	3478	4724	36· 6	6956	4224	54· 8	10434	3724	72·11	13913
9	388	4388	5362	6·11	1392	5112	12·21	2783	4612	25·19	5567	4112	38·16	8350	3612	51·13	11134
10	536	4536	5214	4·16	1119	4964	9· 8	2239	4464	18·16	4477	3964	27·23	6716	3464	37· 7	8955
11	712	4712	5038	3·12	927	4788	7· 1	1854	4288	14· 1	3708	3788	21· 1	5562	3288	28· 2	7416
12	928	4928	4822	2·17	776	4572	5· 9	1552	4072	10·19	3103	3572	16· 4	4655	3072	21·13	6207
13	1180	5180	4570	2· 3	661	4320	4· 6	1322	3820	8·11	2644	3320	12·17	3966	2820	16·23	5288
14	1472	5472	4278	1·17	571	4028	3·10	1141	3528	6·19	2282	3028	10· 4	3423	2528	13·14	4565
15	1812	5812	3938	1· 9	497	3688	2·18	993	3188	5·12	1986	2688	8· 6	2979	2188	11· 1	3973
16	2200	6200	3550	1· 3	436	3300	2· 7	873	2800	4·13	1745	2300	6·19	2618	1800	9· 2	3491
17	2636	6636	3114	0·23	387	2864	1·22	774	2364	3·19	1548	1864	5·16	2322	1364	7·14	3096
18	3132	7132	2618	0·19	345	2368	1·14	689	1868	3· 5	1379	1368	4·19	2068	868	6· 9	2758
19	3684	7684	3066	0·16	309	1816	1· 9	619	1316	2·17	1238	816	4· 1	1857	316	5·10	2476
20	4296	8296	1454	0·14	279	1204	1· 4	559	704	2· 8	1117	204	3·12	1676	0		

The required increase of power and consequent decrease of cargo attendant on the realisation of an increased rate of speed by the agency of steam, as now applied in marine navigation, are strikingly developed by the foregoing Tables, for example:—

By Table No. 1, it appears that a ship of 500 tons' mean displacement, if fitted to run at EIGHT nautical miles per hour, would convey 163 tons of cargo on a passage of 5192 miles; but, if fitted with the increased power required for TWELVE nautical miles per hour, the same vessel would convey 74 tons of cargo on a passage of 2304 miles; being only *half* the cargo and *half* the distance.

By Table No. 3, a ship of 1000 tons' mean displacement, if fitted to run at EIGHT MILES per hour, would convey 341 tons of cargo a distance of 6512 miles; but, if fitted for FOURTEEN MILES per hour, the same vessel would convey 83 tons of cargo a distance of 2114 miles; being only *one-fourth* the cargo and *one-third* the distance.

By Table No. 7, a ship of 2500 tons' mean displacement, if fitted to run at EIGHT MILES per hour, would convey 891 tons of cargo a distance of 8807 miles; but, if fitted for SIXTEEN MILES per hour the same ship would convey 127 tons of cargo a distance of 2199 miles; being only *one-seventh* the cargo and *one-fourth* the distance.

By Table No. 11, a ship of 6000 tons' mean displacement, if fitted to run at EIGHT MILES per hour, would convey 2204 tons of cargo a distance of 11,755 miles; but, if fitted for EIGHTEEN MILES per hour the same vessel would convey 170 tons of cargo a distance of 2325 miles; being only *one-thirteenth* part of the cargo and about *one-fifth* of the distance.

By Table No. 13, a ship of 10,000 tons' mean dis-

placement, if fitted to run at EIGHT MILES per hour, would convey 3724 tons of cargo a distance of 13,913 miles; but, if fitted to run at TWENTY MILES per hour, the same vessel would convey 204 tons a distance of 1676 miles; being only *one-eighteenth* part of the cargo and *one-eighth* of the distance.

The *extreme* limit of SPEED capable of being achieved by a steam-vessel of given size, will, of course, be dependant on the lightness of the hull and equipment, lightness of machinery per H.P., economy of consumption of fuel per H.P., and on the construction of the hull and the engine adaptation thereto, being such as to give a high rate of locomotive performance. These are subjects of practical construction; and it is impossible to assign any definite limits to promissory improvements, or to the hazards that may be recklessly incurred in the pursuit of fame by sacrificing strength to the attainment of lightness; but, as regards each of the above-mentioned particulars, the assumed data on which the Tables, No. 1 to 13, have been calculated, are believed to be favorable for the attainment of a high result, and such as have rarely, if ever, been combined in any one ship. It is therefore submitted that the results indicated by these Tables are of the highest order that present practice will justify being *calculated* upon, however sanguine may be the opinion as to the practicability of these results being surpassed. Without any disparagement therefore of science, and with due appreciation of the improvements which constructive talent may, and undoubtedly will, confer on steam navigation, the following further remarks on the Tables may be adduced as indicating the *limits* of speed and distance that under present circumstances may be reasonably entertained as to the probable capabilities of vessels suitably constructed for

sea service. Referring, therefore, to the Tables, we observe as follows :—

By Table No. 1, it appears that a vessel of 500 tons' mean displacement, may not be expected to attain the speed of 17 nautical miles per hour, but may make a passage of 720 miles at 15 nautical or $17\frac{1}{4}$ statute miles per hour.

By Table No. 2, a vessel of 750 tons' mean displacement may not be expected to attain the speed of 18 nautical miles per hour, but may make a passage of 368 miles at 16 nautical or $18\frac{1}{2}$ statute miles per hour.

By Table No. 3, a vessel of 1000 tons' mean displacement may not be expected to attain the speed of 19 nautical miles per hour, but may make a passage of 357 miles at 17 nautical or $19\frac{1}{2}$ statute miles per hour.

By Table No. 6, a vessel of 2000 tons' mean displacement may not be expected to attain the speed of 20 nautical miles per hour, but may make a passage of 403 miles at 18 nautical or $20\frac{3}{4}$ statute miles per hour.

By Table No. 8, a vessel of 3000 tons' mean displacement may not be expected to attain the speed of 21 nautical miles per hour, but may make a passage of 207 miles at 19 nautical or 22 statute miles per hour.

By Table No. 10, a vessel of 5000 tons' mean displacement may not be expected to attain the speed of 22 nautical miles per hour, but may make a passage of 446 miles at 20 nautical or 23 statute miles per hour, carying about 60 tons of freight.

Thus it appears, that to attain the speed of 20 nautical miles, or 23 statute miles per hour, for a passage of 446 nautical miles, a vessel of about 5000 tons'

mean displacement (probably not less than 4140 tons builders' measure) would be required, and even with a vessel of this magnitude, the displacement would be so appropriated by the weight of machinery, leaving 60 tons only available for cargo, that the vessel could only be regarded as a mail and passenger packet, and not adapted for general merchant service.

It however appears, by Table No. 13, that a ship of the unprecedented size of 10,000 tons' mean displacement, if fitted to run at 20 nautical miles per hour, may be expected to convey 1454 tons of cargo a distance of 279 miles; or, 1204 tons of cargo a distance of 559 miles; or, 704 tons of cargo a distance of 1117 miles; or, 204 tons of cargo a distance of 1676 miles.

Such is the limited commercial result of a vessel, even of the unprecedented size of 10,000 tons' mean displacement (or about 8281 tons, builders' measurement), if fitted to run at 20 nautical miles per hour, viz.:—conveying 204 tons of cargo a distance of 1676 miles only; and if we extend the calculation for the distance of 6000 miles, at the rate of 20 miles per hour, by the agency of steam *as now practised*, it will be found that the calculated result presents an array of figures *commercially* beyond the limit of all serious contemplation, especially when viewed with reference to the mutual relation of SPEED and COST, which is purposed to be the subject of the following Section.

SECTION IV.

THE MUTUAL RELATION OF DISTANCE, SPEED, AND COST OF FREIGHT PER TON; ILLUSTRATED BY TABLES CONSTRUCTED ESPECIALLY WITH REFERENCE TO PASSAGES OF FIVE HUNDRED, ONE THOUSAND, TWO THOUSAND, THREE THOUSAND, FOUR THOUSAND FIVE HUNDRED, AND SIX THOUSAND NAUTICAL MILES.

WITH a view to illustrate the relative CAPABILITIES of steam ships, especially with reference to the comparative COST at which freight would, on the assumed data, be conveyed at different rates of *speed* on passages of given length, the following Tables (Series No. 2) have been constructed for vessels varying from 500 to 10,000 tons of mean displacement, and employed on passages of 500, 1000, 2000, 3000, 4500, and 6000 nautical miles, at rates of speed from 6 to 20 nautical miles an hour. These calculations, like those in the foregoing Tables are based on the assumption that the weight of the hull and equipment, exclusive of the engines, will appropriate 40 per cent. of the mean displacement; that the weight of the engines in complete working order will be one ton per H.P., and the consumption of fuel 4 cwts. per H.P. per day: the UNIT of power (H.P.) being taken at 132·000 lbs. raised one foot per minute.

SERIES 2.—TABLE No. 1.

Calculated for the mean DISPLACEMENT *of* 500 TONS. *Index Number* 862, *and* $H.P. = \frac{P.V.}{182 \cdot 000}$.

SPEED—PER HOUR.	HORSE-POWER.	WEIGHT OF HULL AND ENGINES.	PASSAGE. 500 NAUTICAL MILES.			PASSAGE 1000 NAUTICAL MILES.			PASSAGE. 2000 NAUTICAL MILES.			PASSAGE 3000 NAUTICAL MILES.			PASSAGE 4500 NAUTICAL MILES.			PASSAGE. 6000 NAUTICAL MILES.		
			Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.
N. M.	H. P	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.
6	16	216	3·11	11	278	6·23	22	272	13·21	44	261	20·20	66	250	31· 6	100	234	41·16	133	217
7	25	225	2·23	14	267	5·23	29	260	11·22	59	245	17·21	89	230	26·19	133	208	35·17	178	185
8	37	237	2·14	19	253	5· 5	38	243	10·10	77	224	15·15	115	205	23·16	173	176	31· 6	231	147
9	53	253	2· 8	24	234	4·15	49	222	9· 6	98	197	13·21	147	173	20·20	220	136	27·19	294	99
10	73	273	2· 2	30	211	4· 4	60	196	8· 8	121	166	12·12	182	135	18·18	273	90	25· 0	365	44
11	97	297	1·21	36	184	3·19	73	166	7·14	146	129	11· 9	220	92	17· 1	330	37			
12	126	326	1·18	43	152	3·11	87	130	6·23	175	86	10·10	262	42						
13	160	360	1·14	51	114	3· 5	102	88	6·10	205	37									
14	200	400	1·12	59	70	2·23	119	40												
15	246	446	1· 9	68	19															
16	299	499																		
17	358	558																		
18	425	625																		
19	500	700																		
20	583	783																		

SERIES 2.—TABLE No. 2.

Calculated for the mean DISPLACEMENT *of* 750 TONS. *Index Number* 862, *and* $H.P. = \frac{P.V.}{182 \cdot 000}$.

SPEED—PER HOUR.	HORSE-POWER.	WEIGHT OF HULL AND ENGINES.	PASSAGE. 500 NAUTICAL MILES.			PASSAGE. 1000 NAUTICAL MILES.			PASSAGE. 2000 NAUTICAL MILES.			PASSAGE. 3000 NAUTICAL MILES.			PASSAGE. 4500 NAUTICAL MILES.			PASSAGE. 6000 NAUTICAL MILES.		
			Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.
N. M.	H. P.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	H. P.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.
6	20	320	3·11	13	423	6·23	27	416	13·21	55	402	20·20	83	388	31· 6	125	367	41·16	166	346
7	32	332	2·23	19	408	5·23	38	399	11·22	76	379	17·21	114	360	26·19	171	332	35·17	228	303
8	49	349	2·14	25	387	5· 5	51	375	10·10	102	349	15·15	153	324	23·10	229	286	31· 6	306	247
9	70	370	2· 8	32	363	4·15	64	347	9· 6	129	315	13·21	194	282	20·20	291	234	27·19	388	185
10	96	396	2· 2	40	334	4· 4	80	314	8· 8	160	274	12·12	240	234	18·18	360	174	25· 0	480	114
11	127	427	1·21	48	298	3·19	96	274	7·14	192	226	11· 9	288	178	17· 1	432	106	22·17	577	34
12	165	465	1·18	57	256	3·11	114	227	6·23	229	170	10·10	343	113	15·15	515	27			
13	210	510	1·14	67	206	3· 5	134	172	6·10	269	105	9·15	403	38						
14	262	562	1·12	77	149	2·23	155	110	5·23	311	32									
15	322	622	1· 9	89	83	2.19	178	38												
16	391	691	1· 7	101	8															
17	469	769																		
18	557	857																		
19	655	955																		
20	765	1065																		

SERIES 2.—TABLE No. 3.

Calculated for the mean Displacement *of* 1000 Tons. *Index Number* 862, *and* $H.P. = \frac{P.V.}{183{\cdot}000}$.

SPEED—per hour.	Horse-power.	Weight of Hull and Engines.	Passage 500 Nautical Miles.			Passage 1000 Nautical Miles.			Passage 2000 Nautical Miles.			Passage 3000 Nautical Miles.			Passage 4500 Nautical Miles.			Passage 6000 Nautical Miles.		
			Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.
N.M.	H.P.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.
6	25	425	3·11	17	566	6·23	34	557	13·21	69	540	20·20	104	522	31· 6	156	496	41·16	208	470
7	40	440	2·23	23	548	5·23	47	536	11·22	95	512	17·21	142	488	26·19	214	452	35·17	285	417
8	59	459	2·14	30	525	5· 5	61	510	10·10	122	479	15·15	184	448	23·16	276	402	31· 6	368	356
9	84	484	2· 8	38	496	4·15	77	477	9· 6	155	438	13·21	233	399	20·20	350	341	27·19	466	282
10	116	516	2· 2	48	459	4· 4	96	435	8· 8	193	387	12·12	290	339	18·18	435	266	25· 0	580	194
11	154	554	1·21	58	416	3·19	116	387	7·14	233	329	11· 9	350	271	17· 1	525	183	22·17	700	96
12	200	600	1·18	69	365	3·11	138	330	6·23	277	261	10·10	416	191	15·15	625	87			
13	254	654	1·14	81	305	3· 5	162	264	6·10	325	183	9·15	488	101						
14	317	717	1·12	94	236	2·23	188	188	5.23	377	94									
15	390	790	1· 9	108	155	2·19	216	101												
16	474	874	1· 7	123	64	2·14	246	2												
17	568	968																		
18	675	1075																		
19	794	1194																		
20	926	1326																		

SERIES 2.—TABLE No. 4.

Calculated for the mean DISPLACEMENT *of* 1250 TONS. *Index Number* 862, *and H.P.* $= \frac{P.V.}{182 \cdot 000}$.

SPEED—PER HOUR.	HORSE-POWER.	WEIGHT OF HULL AND ENGINES.	PASSAGE 500 NAUTICAL MILES.			PASSAGE 1000 NAUTICAL MILES.			PASSAGE 2000 NAUTICAL MILES.			PASSAGE 3000 NAUTICAL MILES.			PASSAGE 4500 NAUTICAL MILES.			PASSAGE 6000 NAUTICAL MILES.		
			Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.
N. M.	H. P.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.
6	29	529	3·11	20	711	6·23	40	700	13·21	80	680	20·20	120	660	31· 6	181	630	41·16	241	600
7	46	546	2·23	27	690	5·23	54	676	11·22	109	649	17·21	164	621	26·19	246	580	35·17	328	539
8	69	569	2·14	36	663	5· 5	71	645	10·10	143	609	15·15	215	573	23·10	323	519	31 6	431	465
9	97	597	2· 8	45	631	4·15	89	608	9· 6	179	563	13·21	269	518	20·20	404	451	27·19	538	383
10	134	634	2· 2	55	588	4· 4	111	560	8· 8	223	504	12·12	335	448	18·18	502	364	25· 0	670	281
11	178	678	1·21	67	538	3·19	134	504	7·14	269	437	11· 9	404	369	17· 1	606	268	25·17	809	167
12	232	732	1·18	80	478	3·11	161	437	6·23	322	356	10·10	483	276	15·15	725	155	20·20	966	34
13	295	795	1·14	94	408	3· 5	189	360	6·10	378	265	9·15	567	171	14·10	850	29			
14	368	868	1·12	109	327	2·23	219	272	5·23	438	162									
15	453	953	1· 9	125	234	2·19	251	171	5·13	503	45									
16	550	1050	1· 7	143	128	2·14	286	56												
17	659	1159	1· 5	162	10															
18	783	1283																		
19	921	1421																		
20	1074	1574																		

SERIES 2.—TABLE No. 5.

Calculated for the mean DISPLACEMENT *of* 1500 TONS. *Index Number* 862, *and H.P.* $= \frac{\text{P.V.}}{182 \cdot 000.}$

SPEED—PER HOUR.	HORSE-POWER.	WEIGHT OF HULL AND ENGINES.	PASSAGE. 500 NAUTICAL MILES.			PASSAGE. 1000 NAUTICAL MILES.			PASSAGE. 2000 NAUTICAL MILES.			PASSAGE. 3000 NAUTICAL MILES.			PASSAGE. 4500 NAUTICAL MILES.			PASSAGE. 6000 NAUTICAL MILES.		
			Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.
N. M.	H. P.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	H. P.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.
6	33	633	3·11	22	855	6·23	45	844	13·21	91	821	20·20	137	798	31· 6	206	763	41·16	275	729
7	52	652	2·23	30	832	5·23	61	817	11·22	123	786	17·21	185	755	26·19	278	708	35·17	371	662
8	78	678	2·14	40	801	5· 5	81	781	10·10	162	740	15·15	243	700	23·16	365	639	31· 6	487	578
9	111	711	2· 8	51	763	4·15	102	737	9· 6	205	686	13·21	308	634	20·20	462	557	27·19	616	480
10	152	752	2· 2	63	716	4· 4	126	684	8· 8	253	621	12·12	380	558	18·18	570	463	25· 0	760	368
11	202	802	1·21	76	659	3·19	153	621	7·14	306	544	11· 9	459	468	17· 1	688	353	22·17	918	238
12	262	862	1·18	90	592	3·11	181	547	6·23	363	456	10·10	545	365	15·15	818	228	20·20	1091	92
13	333	933	1·14	106	513	3· 5	213	460	6·10	426	353	9·15	640	246	14·10	960	86			
14	416	1016	1·12	123	422	2·23	247	360	5·23	495	236									
15	512	1112	1· 9	142	316	2.19	284	245	5·13	568	103									
16	621	1221	1· 7	161	198	2.14	323	117												
17	745	1345																		
18	884	1484																		
19	1040	1640																		
20	1213	1813																		

SERIES 2.—TABLE No. 6.

Calculated for the mean DISPLACEMENT *of* 2000 TONS. *Index Number* 862, *and* $H.P. = \frac{P.V.}{182 \cdot 000}$.

SPEED—PER HOUR.	HORSE-POWER.	WEIGHT OF HULL AND ENGINES.	PASSAGE. 500 NAUTICAL MILES.			PASSAGE. 1000 NAUTICAL MILES.			PASSAGE. 2000 NAUTICAL MILES.			PASSAGE 3000 NAUTICAL MILES.			PASSAGE 4500 NAUTICAL MILES.			PASSAGE. 6000 NAUTICAL MILES.		
			Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.
N. M.	H. P.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS	D. H.	TONS.	TONS.
6	40	840	3·11	27	1146	6·23	55	1132	13·21	111	1104	20·20	166	1076	31· 6	250	1035	41·16	333	993
7	63	863	2·23	37	1118	5·23	75	1099	11·22	150	1062	17·21	225	1024	26·19	337	968	35·17	450	912
8	94	894	2·14	48	1082	5· 5	97	1057	10·10	195	1008	15·15	293	959	23·16	440	885	31· 6	587	812
9	134	934	2· 8	62	1035	4·15	124	1003	9· 6	248	941	13·21	372	879	20·20	558	786	27·19	744	693
10	184	984	2· 2	76	978	4· 4	153	939	8· 8	306	862	12·12	460	786	18·18	690	671	25· 0	920	556
11	245	1045	1·21	92	909	3·19	185	862	7·14	371	769	11· 9	556	676	17· 1	835	537	22·17	1113	398
12	317	1117	1·18	110	828	3·11	220	772	6·23	440	662	10·10	660	552	15·15	990	387	20·20	1320	222
13	403	1203	1·14	129	732	3· 5	258	667	6·10	516	538	9·15	775	409	14·10	1162	215	19· 6	1550	22
14	504	1304	1·12	150	621	2·23	300	546	5·23	600	396	8·22	900	246	13· 9	1350	21			
15	620	1420	1· 9	172	494	2·19	344	407	5·13	688	235	8· 8	1033	63						
16	753	1553	1· 7	196	349	2·14	392	250	5· 5	784	54									
17	902	1702	1· 5	221	187	2·11	442	76												
18	1071	1871																		
19	1260	2060																		
20	1469	2269																		

SERIES 2.—TABLE No. 7.

Calculated for the mean DISPLACEMENT *of* 2500 TONS. *Index Number* 862, *and* $H.P. = \frac{P.V.}{182 \cdot 000}$.

SPEED—PER HOUR.	HORSE-POWER.	WEIGHT OF HULL AND ENGINES.	PASSAGE 500 NAUTICAL MILES.			PASSAGE 1000 NAUTICAL MILES.			PASSAGE 2000 NAUTICAL MILES.			PASSAGE 3000 NAUTICAL MILES.			PASSAGE 4500 NAUTICAL MILES.			PASSAGE 6000 NAUTICAL MILES.		
			Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.
N.M.	H.P.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.
6	46	1046	3·11	31	1438	6·23	63	1422	13·21	127	1390	20·20	191	1358	31· 6	287	1310	41·16	383	1262
7	73	1073	2·23	43	1405	5·23	86	1383	11·22	173	1340	17·21	260	1296	26·19	391	1231	35·17	521	1166
8	109	1109	2·14	56	1363	5· 5	113	1333	10·10	227	1276	15·15	340	1220	23·16	510	1135	31· 6	681	1050
9	155	1155	2· 8	71	1309	4·15	143	1273	9· 6	287	1201	13·21	430	1129	20·20	645	1022	27·19	861	914
10	213	1213	2· 2	88	1243	4· 4	177	1198	8· 8	355	1109	12·12	532	1020	18·18	798	887	25· 0	1065	754
11	284	1284	1·21	107	1162	3·19	215	1108	7·14	430	1000	11· 9	645	893	17· 1	968	731	22·17	1290	570
12	368	1368	1·18	127	1068	3·11	255	1004	6·23	511	876	10·10	766	748	15·15	1150	557	20·20	1533	365
13	468	1468	1·14	150	957	3· 5	300	882	6·10	600	732	9·15	900	582	14·10	1350	357	19· 6	1800	132
14	585	1585	1·12	174	828	2·23	348	740	5.23	696	566	8·22	1044	392	13· 9	1566	131			
15	720	1720	1· 9	200	680	2·19	400	580	5·13	800	380	8· 8	1200	180						
16	873	1873	1· 7	227	513	2·14	454	399	5· 5	909	172									
17	1047	2047	1· 5	256	325	2·11	513	196												
18	1243	2243																		
19	1462	2462																		
20	1705	2705																		

SERIES 2.—TABLE No. 8.

Calculated for the mean Displacement *of* 3000 Tons. *Index Number* 862, *and* $H.P. = \frac{\text{P.V.}}{182\cdot 000}$.

Speed—per hour.	Horse-power.	Weight of Hull and Engines.	Passage. 500 Nautical Miles.			Passage. 1000 Nautical Miles.			Passage. 2000 Nautical Miles.			Passage. 3000 Nautical Miles.			Passage 4500 Nautical Miles.			Passage. 6000 Nautical Miles.		
			Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.
N. M.	H. P.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS	D. H.	TONS.	TONS.	D. H.	TONS	TONS.	D. H.	TONS.	TONS.
6	52	1252	3·11	36	1729	6·23	72	1711	13·21	144	1675	20·20	216	1639	31· 6	325	1585	41·16	433	1531
7	83	1283	2·23	49	1692	5·23	98	1667	11·22	197	1617	17·21	296	1568	26·19	444	1494	35·17	592	1420
8	123	1323	2·14	64	1644	5· 5	128	1612	10·10	256	1548	15·15	384	1484	23·10	576	1388	31· 6	768	1292
9	175	1375	2· 8	81	1584	4·15	162	1543	9· 6	324	1462	13·21	486	1381	20·20	729	1260	27·19	972	1138
10	241	1441	2· 2	100	1508	4· 4	200	1458	8· 8	401	1358	12·12	602	1257	18·18	903	1107	25· 0	1205	956
11	320	1520	1·21	121	1419	3·19	242	1358	7·14	484	1237	11· 9	727	1116	17· 1	1090	934	22·17	1454	752
12	416	1616	1·18	144	1311	3·11	288	1239	6·23	577	1095	10·10	866	950	15·15	1300	734	20·20	1733	517
13	529	1729	1·14	169	1186	3· 5	339	1100	6·10	678	931	9·15	1017	761	14·10	1525	508	19· 6	2034	253
14	661	1861	1·12	196	1040	2·23	393	942	5·23	786	745	8·22	1180	548	13· 9	1770	253			
15	813	2013	1· 9	225	874	2·19	451	761	5·13	903	535	8· 8	1355	309						
16	987	2187	1· 7	257	684	2·14	514	555	5· 5	1028	298	7·19	1542	41						
17	1183	2383	1· 5	290	472	2·11	580	327	4·22	1160	37									
18	1405	2605	1· 4	325	232	2· 8	650	69												
19	1652	2852																		
20	1927	3127																		

SERIES 2.—TABLE No. 9.

Calculated for the mean DISPLACEMENT *of* 4000 TONS. *Index Number* 862, *and H.P.* $\doteq \frac{\text{P.V.}}{182\cdot000}$

SPEED—PERHOUR.	HORSE-POWER.	WEIGHT OF HULL AND ENGINES.	PASSAGE. 500 NAUTICAL MILES.			PASSAGE. 1000 NAUTICAL MILES.			PASSAGE. 2000 NAUTICAL MILES.			PASSAGE. 3000 NAUTICAL MILES.			PASSAGE. 4500 NAUTICAL MILES.			PASSAGE. 6000 NAUTICAL MILES.		
			Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.
N. M.	H. P.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	H. P.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.
6	64	1664	3·11	44	2313	6·23	88	2291	13·21	177	2247	20·20	266	2202	31· 6	400	2136	41·16	533	2069
7	100	1700	2·23	59	2270	5·23	119	2240	11·22	238	2180	17·21	357	2121	26·19	535	2032	35·17	714	1942
8	148	1748	2·14	77	2213	5· 5	154	2174	10·10	308	2097	15·15	462	2021	23·10	693	1905	31· 6	925	1789
9	212	1812	2· 8	98	2138	4·15	196	2089	9· 6	392	1991	13·21	588	1893	20·20	883	1746	27·19	1177	1599
10	292	1892	2· 2	121	2047	4· 4	243	1986	8· 8	480	1864	12·12	730	1743	18·18	1095	1560	25· 0	1460	1378
11	388	1988	1·21	146	1938	3·19	293	1865	7·14	587	1718	11· 9	881	1571	17· 1	1322	1350	22·17	1763	1130
12	504	2104	1·18	175	1808	3·11	350	1721	6·23	700	1546	10·10	1050	1371	15·15	1575	1108	20·20	2100	846
13	640	2240	1·14	205	1657	3· 5	410	1554	6·10	820	1349	9·15	1230	1144	14·10	1846	836	19· 6	2461	529
14	800	2400	1·12	238	1480	2·23	476	1361	5·23	952	1123	8·22	1428	885	13· 9	2142	528	17·21	2857	171
15	984	2584	1· 9	273	1279	2.19	546	1142	5·13	1093	869	8· 8	1640	596	12·12	2460	186			
16	1196	2796	1· 7	311	1048	2.14	622	893	5· 5	1245	581	7·19	1868	269						
17	1432	3032	1· 5	350	792	2·11	701	617	4·22	1403	266									
18	1700	3300	1· 4	393	503	2· 8	787	306												
19	2000	3600	1· 2	438	180															
20	2333	3933																		

SERIES 2.—TABLE No. 10.

Calculated for the mean DISPLACEMENT *of* 5000 TONS. *Index Number* 862, *and* $H.P. = \frac{P.V.}{132\cdot000}$.

SPEED—PER HOUR.	HORSE-POWER.	WEIGHT OF HULL AND ENGINES.	PASSAGE 500 NAUTICAL MILES.			PASSAGE 1000 NAUTICAL MILES.			PASSAGE 2000 NAUTICAL MILES.			PASSAGE 3000 NAUTICAL MILES.			PASSAGE 4500 NAUTICAL MILES.			PASSAGE 6000 NAUTICAL MILES.		
			Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.
N.M.	H.P.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.
6	73	2073	3·11	50	2901	6·23	101	2876	13·21	202	2825	20·20	304	2774	31· 6	456	2698	41·16	608	2622
7	115	2115	2·23	68	2850	5·23	136	2816	11·22	273	2748	17·21	410	2679	26·19	616	2576	35·17	821	2474
8	172	2172	2·14	89	2783	5· 5	179	2738	10·10	358	2648	15·15	537	2559	23·10	806	2424	31· 6	1075	2290
9	245	2245	2· 8	113	2698	4·15	226	2641	9· 6	453	2528	13·21	680	2414	20·20	1020	2244	27·19	1361	2074
10	336	2336	2· 2	140	2594	4· 4	280	2524	8· 8	560	2384	12·12	840	2244	18·18	1260	2034	25· 0	1680	1824
11	448	2448	1·21	169	2467	3·19	339	2382	7·14	678	2212	11· 9	1018	2042	17· 1	1527	1788	22·17	2036	1533
12	581	2581	1·18	201	2318	3·11	403	2217	6·23	806	2015	10·10	1210	1813	15·15	1815	1511	20·20	2420	1208
13	739	2739	1·14	236	2142	3· 5	473	2024	6·10	947	1787	9·15	1421	1550	14·10	2131	1195	19· 6	2842	839
14	923	2923	1·12	274	1939	2·23	549	1802	5·23	1098	1527	8·22	1648	1252	13· 9	2472	840	17·21	3296	428
15	1135	3135	1· 9	315	1707	2·19	630	1549	5·13	1261	1234	8· 8	1891	919	12·12	2837	446			
16	1377	3377	1· 7	358	1443	2·14	717	1264	5· 5	1434	905	7·19	2151	547	11·17	3227	9			
17	1652	3652	1· 5	404	1145	2·11	809	943	4·22	1619	538	7· 8	2429	133						
18	1961	3961	1· 4	453	812	2· 8	907	585	4·15	1815	131									
19	2307	4307	1· 2	505	440	2· 5	1011	187												
20	2690	4690	1· 1	560	29															

SERIES 2.—TABLE No. 11.

Calculated for the mean DISPLACEMENT *of* 6000 TONS. *Index Number* 871, *and* $H.P. = \frac{P.V.}{182{\cdot}000}$.

SPEED—PER HOUR.	HORSE-POWER.	WEIGHT OF HULL AND ENGINES.	PASSAGE 500 NAUTICAL MILES.			PASSAGE 1000 NAUTICAL MILES.			PASSAGE 2000 NAUTICAL MILES.			PASSAGE 3000 NAUTICAL MILES.			PASSAGE 4500 NAUTICAL MILES.			PASSAGE 6000 NAUTICAL MILES.		
			Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.
N. M.	H. P.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.
6	83	2483	3·11	57	3488	6·23	115	3459	13·21	230	3401	20·20	345	3344	31· 6	518	3257	41·16	691	3171
7	131	2531	2·23	77	3430	5·23	155	3391	11·22	311	3313	17·21	467	3235	26·19	701	3118	35·17	935	3001
8	196	2596	2·14	102	3352	5· 5	204	3301	10·10	408	3199	15·15	612	3097	23·10	918	2944	31· 6	1225	2791
9	279	2679	2· 8	129	3256	4·15	258	3191	9· 6	516	3062	13·21	775	2933	20·20	1162	2739	27·19	1550	2546
10	383	2783	2· 2	159	3137	4· 4	319	3057	8· 8	638	2898	12·12	957	2738	18·18	1436	2498	25· 0	1915	2259
11	510	2910	1·21	193	2993	3·19	386	2896	7·14	772	2703	11· 9	1159	2510	17· 1	1738	2220	22·17	2318	1930
12	660	3060	1·18	229	2825	3·11	458	2710	6·23	916	2481	10·10	1375	2252	15·15	2062	1908	20·20	2750	1565
13	840	3240	1·14	269	2625	3· 5	538	2490	6·10	1076	2221	9·15	1615	1952	14·10	2423	1548	19· 6	3230	1144
14	1049	3449	1·12	312	2395	2·23	624	2239	5·23	1248	1926	8·22	1873	1614	13· 9	2809	1146	17·21	3746	677
15	1291	3691	1· 9	358	2129	2·19	717	1950	5·13	1434	1591	8· 8	2151	1233	12·12	3227	695	16·16	4308	157
16	1567	3967	1· 7	408	1828	2·14	816	1624	5· 5	1632	1216	7·19	2448	808	11·17	3672	196			
17	1878	4278	1· 5	460	1491	2·11	920	1261	4·22	1841	801	7· 8	2761	341						
18	2230	4630	1· 4	516	1111	2· 8	1032	853	4·15	2064	337									
19	2623	5023	1· 2	575	689	2· 5	1150	401												
20	3059	5459	1· 1	637	222															

SERIES 2.—TABLE No. 12.

Calculated for the mean Displacement *of* 8000 Tons. *Index Number* 871, *and H.P.* $= \frac{P.V.}{182 \cdot 000}$.

SPEED—PER HOUR.	Horse-power.	Weight of Hull and Engines.	Passage. 500 Nautical Miles. Time.	Coal.	Cargo.	Passage. 1000 Nautical Miles. Time.	Coal.	Cargo.	Passage. 2000 Nautical Miles. Time.	Coal.	Cargo.	Passage. 3000 Nautical Miles. Time.	Coal.	Cargo.	Passage. 4500 Nautical Miles. Time.	Coal.	Cargo.	Passage. 6000 Nautical Miles. Time.	Coal.	Cargo.
N. M.	H. P.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS	D. H.	TONS.	TONS.
6	100	3300	3·11	69	4665	6·23	138	4630	13·21	277	4561	20·20	416	4491	31· 6	625	4387	41·16	833	4283
7	159	3359	2·23	94	4593	5·23	189	4546	11·22	378	4451	17·21	567	4357	26·19	851	4215	35·17	1135	4073
8	237	3437	2·14	123	4501	5· 5	246	4439	10·10	493	4316	15·15	740	4192	23·10	1110	4007	31· 6	1481	3822
9	338	3538	2· 8	156	4383	4·15	312	4305	9· 6	625	4149	13·21	938	3992	20·20	1408	3757	27·19	1877	3523
10	463	3663	2· 2	192	4240	4· 4	385	4144	8· 8	771	3951	12·12	1157	3758	18·18	1736	3468	25· 0	2315	3179
11	616	3816	1·21	233	4067	3·19	466	3950	7·14	933	3717	11· 9	1400	3484	17· 1	2100	3134	22·17	2800	2784
12	800	4000	1·18	277	3861	3·11	555	3722	6·23	1111	3444	10·10	1666	3166	15·15	2500	2750	20·20	3333	2333
13	1017	4217	1·14	325	3620	3· 5	651	3457	6·10	1303	3131	9·15	1955	2805	14·10	2933	2316	19· 6	3911	1827
14	1270	4470	1·12	377	3341	2·23	755	3152	5·23	1511	2774	8·22	2267	2396	13· 9	3401	1829	17·21	4535	1262
15	1562	4762	1· 9	433	3021	2·19	867	2804	5·13	1735	2370	8· 8	2603	1936	12·12	3905	1285	16·16	5206	634
16	1897	5097	1· 7	494	2656	2·14	988	2407	5· 5	1976	1914	7·19	2964	1420	11·17	4446	679			
17	2274	5474	1· 5	557	2247	2·11	1114	1968	4·22	2229	1411	7· 8	3344	853						
18	2700	5900	1· 4	625	1787	2· 8	1250	1475	4·15	2500	850	6·23	3750	225						
19	3176	6376	1· 2	696	1275	2· 5	1392	927	4· 9	2785	231									
20	3704	6904	1· 1	771	710	2· 2	1543	324												

SERIES 2.—TABLE No. 13.

Calculated for the mean Displacement *of* 10,000 Tons. *Index Number* 871, *and H.P.* = $\frac{\text{P.V.}}{132\cdot000}$

SPEED—per hour.	Horse-power.	Weight of Hull and Engines.	Passage 500 Nautical Miles.			Passage 1000 Nautical Miles.			Passage 2000 Nautical Miles.			Passage 3000 Nautical Miles.			Passage 4500 Nautical Miles.			Passage 6000 Nautical Miles.		
			Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.
N.M.	H.P.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.	D. H.	TONS.	TONS.
6	116	4116	3·11	80	5843	6·23	161	5803	13·21	322	5722	20·20	483	5642	31· 6	725	5521	41·16	966	5400
7	184	4184	2·23	109	5761	5·23	219	5706	11·22	438	5596	17·21	657	5487	26·19	985	5323	35·17	1314	5158
8	276	4276	2·14	143	5652	5· 5	287	5580	10·10	575	5436	15·15	862	5292	23·10	1293	5077	31· 6	1725	4861
9	388	4388	2· 8	179	5522	4·15	359	5432	9· 6	718	5252	13·21	1077	5073	20·20	1616	4803	27·19	2155	4534
10	536	4536	2· 2	223	5352	4· 4	446	5240	8· 8	893	5017	12·12	1340	4794	18·18	2010	4459	25· 0	2680	4124
11	712	4712	1·21	269	5153	3·19	539	5018	7·14	1078	4748	11· 9	1618	4478	17· 1	2427	4074	22·17	3236	3669
12	928	4928	1·18	322	4910	3·11	644	4749	6·23	1288	4427	10·10	1933	4105	15·15	2900	3622	20·20	3866	3138
13	1180	5180	1·14	378	4630	3· 5	756	4441	6·10	1512	4063	9·15	2269	3685	14·10	3403	3118	19· 6	4538	2550
14	1472	5472	1·12	438	4308	2·23	876	4089	5·23	1752	3651	8·22	2628	3213	13· 9	3942	2556	17·21	5257	1899
15	1812	5812	1· 9	503	3936	2·19	1006	3684	5·13	2013	3181	8· 8	3020	2678	12·12	4530	1923	16·16	6040	1168
16	2200	6200	1· 7	572	3513	2·14	1145	3226	5· 5	2291	2653	7·19	3437	2081	11·17	5156	1221	15·15	6875	362
17	2636	6636	1· 5	646	3040	2·11	1292	2717	4·22	2584	2071	7· 8	3876	1425	11· 1	5814	456			
18	3132	7132	1· 4	725	2505	2· 8	1450	2143	4·15	2900	1418	6·23	4350	693						
19	3684	7684	1· 2	807	1912	2· 5	1615	1508	4· 9	3231	700									
20	4296	8296	1· 1	895	1256	2· 2	1790	809												

It has been previously observed that the larger the vessel the greater will be its capabilities in proportion to the power employed; but, constant employment and full freight are indispensable to this condition in favor of large vessels, and the limitations of mercantile Investment, Insurance, and Harbour accommodation all tend to restrict the size of vessel that might otherwise be most advantageously employed. It is, therefore, purposed to illustrate the mutual relations of SPEED and COST by assuming, for example, the employment of a vessel of large size, say 5000 tons' mean displacement (being about 4140 tonnage builders' measurement), and ascertaining, in the first place, the *proportional* scale of COST that will be incurred in the conveyance of cargo *per ton* at different rates of speed and on passages of various length, say 1000, 3000, and 6000 nautical miles.

Now suppose, for example, that the passage be 1000 miles, and that, for brevity, we confine our remarks to the engine department only; which, indeed, will be the department of expense, chiefly affected by variations in the rate of speed. By reference to Table No. 10, it appears that the vessel of 5000 tons' mean displacement, if fitted to run at the speed of EIGHT NAUTICAL MILES per hour, will require 172 H.P., and a cargo of 2738 tons will be conveyed 1000 miles in five days five hours; being equivalent to one day's employment of $\frac{33}{100}$ H.P. *per ton* of goods.

If fitted to run at TEN NAUTICAL MILES an hour, the vessel will require 336 H.P., the cargo will be reduced to 2524 tons, and the time to four days four hours; being equivalent to one day's employment of $\frac{55}{100}$ H.P. *per ton* of goods nearly.

If fitted to run at TWELVE NAUTICAL MILES an hour, the vessel will require 581 H.P., the cargo will be reduced

to 2217 tons, and the time to three days eleven hours; being equivalent to one day's employment of $\frac{91}{100}$ H.P. *per ton* of goods.

If fitted to run at FOURTEEN MILES an hour, the vessel will require 923 H.P., the cargo will be reduced to 1802 tons, and the time to two days twenty-three hours; being equivalent to one day's employment of $1\frac{52}{100}$ H.P. *per ton* of goods.

If fitted to run at SIXTEEN MILES per hour, the vessel will require 1377 H.P., the cargo will be reduced to 1264 tons, and the time to two days fourteen hours; being equivalent to one day's employment of $2\frac{86}{100}$ H.P. *per ton* of goods.

If fitted to run at EIGHTEEN MILES per hour, the vessel will require 1961 H.P., the cargo will be reduced to 585 tons, and the time to two days eight hours; being equivalent to one day's employment of $7\frac{75}{100}$ H.P. *per ton* of goods.

And if fitted to run at TWENTY MILES per hour, there will be no displacement available for mercantile cargo.

Assuming, now, that the cost per ton of goods will be in proportion to the amount of power and tonnage employed to do the work, it appears that the cost *per ton of goods* of performing this passage of 1000 miles, at the respective speeds of 8, 10, 12, 14, 16, and 18 miles, will be proportional to the numbers—$\frac{33}{100}$, $\frac{55}{100}$, $\frac{91}{100}$, $1\frac{52}{100}$, $2\frac{86}{100}$, and $7\frac{75}{100}$, which are proportional to the numbers 33, 55, 91, 152, 286, and 775, or nearly as 1, 2, 3, 5, 9, and 23.

Hence, it appears, that in the case of the ONE THOUSAND MILES passage above referred to, the cost of freight *per ton of goods* at TEN MILES per hour, will require to be nearly the *double* of the rate at EIGHT MILES per hour.

The cost per ton at TWELVE MILES per hour will require to be *three times* the rate at EIGHT MILES.

The cost per ton at FOURTEEN MILES per hour will require to be *five times* the rate at EIGHT MILES.

The cost per ton at SIXTEEN MILES per hour will require to be *nine times* the rate at EIGHT MILES.

The cost per ton at EIGHTEEN MILES per hour will require to be *twenty-three times* the rate at EIGHT MILES.

And at TWENTY MILES per hour there will be *no displacement* available for mercantile cargo.

By applying the same process of calculation to a ship of 5000 tons' mean displacement, making a passage of THREE THOUSAND MILES, we shall find that, at TEN MILES an hour, the cost of freight per ton will require to be double the rate of freight at EIGHT MILES.

The cost per ton at TWELVE MILES will require to be three times the rate at EIGHT MILES.

The cost per ton at FOURTEEN MILES will require to be six times the rate at EIGHT MILES.

The cost per ton at SIXTEEN MILES will require to be twenty times the rate at EIGHT MILES.

And at EIGHTEEN MILES per hour there will be *no displacement* available for mercantile cargo.

Finally, by applying the same process of calculation to a ship of 5000 tons' mean displacement on a passage of 6000 miles, it will be found that the cost of freight per ton at TEN MILES per hour will require to be *double* the rate at EIGHT MILES.

The cost per ton at TWELVE MILES per hour will require to be about *five times* the rate at EIGHT MILES.

The cost per ton at FOURTEEN MILES per hour will be about *sixteen times* the rate at EIGHT MILES.

And at SIXTEEN MILES per hour there will be *no displacement* available for mercantile cargo.

Hence, it appears, that for voyages of 1000 miles and upwards, without re-coaling, the speed of ten nautical miles per hour would involve about *double* the cost *per ton* of eight miles, and may, therefore, be regarded as the extreme limit that can be generally entertained for the mercantile purpose of goods' conveyance; and that the attainment on long passages of a higher rate of speed than ten miles (though admissibly practicable) would involve obligations altogether of an exceptional character, such as the special service of despatches, mails, passengers, specie, and the most valuable description of goods can only meet.

It now appears desirable to arrive at some approximately *definite* view of the extent to which the cost of the conveyance of cargo is cheapened, according as the work may be done by vessels of increased magnitude, for example:—1250, 2500, and 5000 tons' mean displacement.

By Table No. 4, at eight miles per hour, a ship of 1250 tons' displacement, with 69 H.P., will convey 465 tons of cargo on a passage of 6000 miles in thirty-one days six hours, being equivalent to one days' employment of 84 tons of shipping and $4\frac{6}{10}$ H.P. *per ton* of goods.

By Table No. 7, at eight miles per hour, a ship of 2500 tons' displacement and 109 H.P. will convey 1050 tons of cargo the same distance (6000 miles) in the same time, viz., thirty-one days six hours; being equivalent to one day's employment of 74 tons of shipping and $3\frac{2}{10}$ H.P. per ton of goods.

By Table No. 10, at eight miles per hour, a ship of 5000 tons' displacement and 172 H.P. will convey 2290 tons of cargo the same distance (6000 miles) in the same time; being equivalent to one day's work of 68 tons of shipping and $2\frac{8}{10}$ H.P. per ton of goods.

It appears, therefore, that in the SHIPPING department the *reduction* of cost per ton of cargo, consequent on the *increasing* size of the SHIP, namely, 1250, 2500, and 5000 tons of mean displacement, will be in the proportion of 84, 74, and 68, which numbers are in the proportion of 100, 88, and 81, and in the ENGINE department, the reduction of cost per ton of cargo will be in proportion to the numbers $4\frac{6}{10}$, $3\frac{2}{10}$, and $2\frac{8}{10}$, which numbers are in the proportion of 100, 70, and 50.

Hence, in the case under consideration, namely, a passage of 6000 miles, steaming at the mean speed of eight miles per hour, by increasing the size of the ship from 1250 to 5000 tons of mean displacement, the reduction of cost per ton of cargo amounts in the shipping department to 19 per cent., and in the engine department to 50 per cent. If, moreover, the size of the ship be further extended from 5000 tons of mean displacement to the unprecedented size of 10,000 tons, the rate of freight in the shipping department will be further reduced about 8 per cent., and in the engine department the reduction will be about 20 per cent. It may, however, be observed that this source of commercial economy in favor of the ship of the unprecedented size of 10,000 tons' displacement will again be altogether sacrificed if, on the strength of it, we attempt to run the ship of 10,000 tons' mean displacement at *nine miles* per hour in competition with ships of 5000 tons' mean displacement running at *eight miles* per hour, and carrying, on the aggregate, the same quantity of goods.

In all the foregoing Tables the speed has been calculated with reference to the STEAM-POWER alone, on which the *regularity* of steam-ship voyages will be mainly dependent: the influence of the wind may, in fact, be regarded as an obstruction to the *regular* attainment of high speed; for, a

favorable wind, though helping a vessel when steaming at the speed of *eight* nautical miles per hour, may afford no aid, or even *oppose* the vessel, when steaming at *twelve* miles per hour; and, an adverse wind will obstruct the vessel, if steaming at high speed, in a far greater ratio than it would the low speed ship.

It is, therefore, presumed to have been sufficiently shown by the foregoing calculations and deductions therefrom (though avowedly based on approximate data), that extreme caution ought to attend all mercantile contracts in regard to the obligation of maintaining such a rate of speed for a *long passage* as exceeds the rate at which the wind may be expected to partially co-operate with the steam-power; it is also presumed to have been shown how greatly it is to be apprehended that various projects, now publicly promulgated, and confidently professing to undertake the regular performance of very long passages at high rates of speed, (for instance, fifteen nautical miles per hour and upwards) are based on expectations not commercially justified by the relation which, at present, actually subsists between steam-ship displacement, power, speed, and COST of freight *per ton;* at least, if the probability of the due fulfilment of such projects is to be judged of by the locomotive capability that has, hitherto, been practically realized by the most successful steam-vessels of the present day.

SECTION V.

INVESTIGATION AS TO THE COMPARATIVE EXTENT TO WHICH THE COST OF FREIGHT PER TON IS AFFECTED BY DIFFERENCES OF ORIGINAL CONSTRUCTION AS REGARDS THE LOCOMOTIVE PROPERTIES OF DIFFERENT SHIPS, OR BY DIFFERENT DEGREES OF FALLING OFF IN THE WORKING CONDITION OF THE HULL, ENGINES, AND BOILERS OF THE SAME SHIP.

THE previous Sections constitute an example of a system of calculation whereby the mercantile CAPABILITIES of a ship and the mutual relation of Speed and Cost may be approximately determined. It is now proposed, by an analogous system of investigation, to deduce an approximate estimate of the commercial advantage in regard to the COST of freight per ton that attends the employment of ships *suitably* constructed for the service on which they may be employed, as compared with vessels of *inferior* adaptation. By this investigation the comparative financial balance of outlay and income, which may be expected of any one vessel as compared with another, may be equitably apportioned, the determination of which issue will, it is conceived, greatly conduce to the effective DIRECTION and MANAGEMENT of mercantile steam shipping, not only in matters of financial economy, but also in so far that on a vessel failing to fulfil an assigned service, a line of discrimi-

nation may be drawn as to the degree in which such failure may be attributable to faults of original construction, producing a low scale of locomotive efficiency, or to defective measures in matters of direction, or of personal management and command. Moreover, steam-ship proprietors will thus be enabled to determine the relative value of their STOCK, not indeed as respects the intrinsic value of the respective ships, but as respects their relative working properties and consequent value for any special service. Each vessel may thus be assigned to its most appropriate duty, and vessels manifestly of an unsuitable adaptation for one Line of Trade may be otherwise employed or disposed of, instead of being put upon services which they are thus *constructively* inadequate to perform: for example, a vessel may be well adapted for the economical conveyance of cargo at eight miles per hour, but by being employed upon a service demanding a higher rate of speed, and failing, the SHIP is held to be inefficient, the STOCK becomes unduly depreciated, and incapacity of DIRECTION, the real cause of the failure, escapes unobserved. With a view, therefore, to compare the mercantile results to be fairly expected of steam vessels under different conditions of locomotive efficiency, the following Table (G) has been arranged to shew, in juxtaposition, the extent to which the power (H.P.) is affected by the different degrees of SCIENTIFIC SKILL with which different vessels may have been *originally* constructed, or by various degrees of *falling off*, as regards working condition, to which the hull and machinery of steam ships is liable. The relative degrees of efficiency being indicated by the index numbers, 862, 792, 664, and 602, assumed as the base of the calculation by way of example, and the UNIT of power (H.P.) being taken as equivalent to 132,000 lbs., raised one foot per minute, as in all the previous calculations.

TABLE G.

SPEED PER HOUR.	INDEX NUMBERS.	DISPLACEMENT IN TONS.												
		500	750	1000	1250	1500	2000	2500	3000	4000	5000	6000	8000	10,000
N. M.		H. P.	H. P.	H. P.	H. P.	H. P	H. P.	H. P	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
6	862	16	20	25	29	33	40	46	52	64	73	83	100	116
	792	17	23	27	32	36	43	50	57	69	80	90	109	127
	664	21	27	33	38	43	52	60	68	82	95	108	130	151
	602	23	30	36	41	47	57	66	75	90	105	118	143	166
7	862	25	32	40	46	52	63	73	83	100	115	131	159	184
	792	27	36	43	50	57	69	80	90	109	127	143	174	201
	664	33	43	52	60	68	82	95	108	130	151	171	207	240
	602	36	47	57	66	75	90	105	118	143	166	188	227	264
8	862	37	49	59	69	78	94	109	123	148	172	196	237	276
	792	41	53	65	75	85	103	119	135	163	189	214	259	300
	664	49	64	77	90	101	123	142	161	195	226	255	309	359
	602	54	70	85	98	111	135	156	177	214	248	281	340	394
9	862	53	70	84	97	111	134	155	175	212	245	279	338	388
	792	58	76	92	107	121	146	170	192	232	270	304	369	428
	664	69	91	110	128	144	175	203	229	277	322	363	440	511
	602	76	100	121	140	159	192	223	252	305	354	400	484	562
10	862	73	96	116	134	152	184	213	241	292	336	383	463	536
	792	79	104	127	147	166	201	233	263	319	370	418	506	587
	664	95	125	151	175	198	240	278	314	380	441	498	604	700
	602	105	137	166	192	217	264	306	345	418	485	548	664	771
11	862	97	127	154	178	202	245	284	320	388	448	510	616	712
	792	106	139	168	195	221	267	310	350	424	492	556	673	781
	664	127	166	201	233	263	319	370	418	506	587	663	804	932
	602	139	182	221	256	289	351	407	459	557	646	730	884	1026
12	862	126	165	200	232	262	317	368	416	504	581	660	800	928
	792	138	180	219	254	286	347	402	455	551	639	722	874	1014
	664	164	215	261	303	342	414	480	542	657	762	861	1043	1210
	602	181	237	287	333	376	455	528	596	722	838	947	1148	1331
13	862	160	210	254	295	333	403	468	529	640	739	840	1017	1180
	792	175	229	278	322	364	441	512	578	700	812	917	1111	1289
	664	209	274	332	385	434	526	610	690	835	969	1094	1326	1539
	602	230	301	365	423	478	579	672	758	919	1067	1205	1459	1693
14	862	200	262	317	368	416	504	585	661	800	923	1049	1270	1472
	792	219	286	347	403	455	551	639	722	874	1014	1146	1388	1611
	664	261	342	414	481	543	657	763	861	1043	1211	1367	1656	1922
	602	287	376	456	529	597	723	839	947	1147	1332	1504	1823	2115
15	862	246	322	390	453	512	620	720	813	984	1135	1291	1562	1812
	792	269	352	427	495	559	678	786	888	1075	1248	1409	1707	1982
	664	321	420	509	591	667	809	938	1059	1283	1489	1682	2037	2364
	602	353	463	560	650	735	890	1033	1165	1411	1639	1851	2242	2602
16	862	299	391	474	550	621	753	873	987	1196	1377	1567	1897	2200
	792	326	427	518	601	679	822	954	1077	1305	1515	1710	2072	2405
	664	389	510	618	717	810	981	1138	1286	1558	1807	2041	2473	2869
	602	429	561	680	789	892	1080	1253	1414	1712	1989	2246	2721	3158

The foregoing Table (G) shows, in juxtaposition, the gradually *increasing* power that is required to propel vessels of given displacement, at a given speed, according to the gradually *decreasing* locomotive efficiency of the vessels as indicated by the index numbers, 862, 792, 664, and 602 respectively ; which numbers have been preferred for illustration as being the index numbers of vessels of a known type of construction, previously referred to in Statement No. 2, page 11, and for which the mutual relations of Displacement, Power, and Speed have been partially calculated in Tables A, B, C, D. The results, as regards the all-important item of POWER being thus brought into comparison, the exposition shows not merely the *differences* of power that vessels of the *same displacement*, but of the *different types* referred to, would require, if employed on a station demanding a given rate of speed, but also the different degrees of power to which the machinery of a *given ship* will require to be *forced* (for marine engines and boilers may be expressly adapted for being capable of exerting a power beyond the limit assigned for their ordinary and constant work,) according as the locomotive properties of the vessel may have *fallen off* by reason of foul bottom, defective machinery, neglectful management, bad stowage, or other cause. These liabilities to falling off in the condition of ships, indicate the expediency of all steam vessels being supplied with boiler-power in excess of the power absolutely required for performing the service for which the vessel may have been constructed ; and, as in any ship when in its best condition, at a given draught or displacement, the rate of speed corresponding to a given amount of working power should be always known, it follows that any material falling off of speed will indicate the existence of defect, either to be remedied or else otherwise met by compensating measures, such for instance, as

an increased supply of coal to the *sacrifice of cargo*, and working the engines up to greater power, in order that the vessel may still keep time.

For example, referring to Table G, take a vessel of 3000 tons' displacement, of which the ascertained index number may have been 862, this vessel, if in good condition, may be expected to run at *ten* nautical miles per hour, with 241 H.P.; if, however, we find on test-trial that the speed has *fallen off* to *nine* miles per hour with the engines working at 229 H.P., the index number of the ship in this condition will then be 664, and her continued employment on the *ten* mile service will require (according to Table G) that the working power be forced up to 314 H.P.—being 73 H.P. beyond the original requirement for the *ten* mile speed. If, now, the boilers on board will not supply the required quantity of steam for this additional 73 H.P. being developed by the engines, the vessel will be unfit for the service in question, but if the boilers will afford the required quantity of steam, and the engines be fit to use it, then the ten mile service will still be practicable, but the extra cost of running the vessel in this defective condition will be not only the cost of the extra quantity of fuel that will be consumed, corresponding to the extra power now required, but the displacement available for freight will also be reduced, thereby enhancing the COST of freight *per ton* in a compound ratio; and it is now purposed to investigate, approximately, the *proportional extent* to which the COST of freight *per ton* will be thus enhanced in consequence of such defective condition of the vessel; to facilitate this enquiry the following Table (H) has been compiled, showing the extent to which the displacement *available for cargo* is affected by differences of CONSTRUCTIVE MERIT, as indicated by the *differences* of index number at which the vessel may be classed.

TABLE H.

Showing the extent to which the Displacement *available for* Cargo *is affected by differences of steam-ship* CONSTRUCTIVE MERIT *or* WORKING CONDITION, *as indicated by varations of the Index Number at which the vessel may be classed.*

Assumed { Mean Displacement and Length of Passage.	Speed per Hour.	Time of Passage.	Index Number, 862. Power.	Index Number, 862. Coal.	Index Number, 862. Cargo.	Index Number, 792. Power.	Index Number, 792. Coal.	Index Number, 792. Cargo.	Index Number, 664. Power.	Index Number, 664. Coal.	Index Number, 664. Cargo.	Index Number, 602. Power.	Index Number, 602. Coal.	Index Number, 602. Cargo.
	N. M.	D. H.	H. P.	Tons.	Tons.	H. P.	Tons.	Tons.	H. P.	Tons.	Tons.	H. P.	Tons.	Tons.
	8	15·15	123	384	1485	135	422	1454	161	503	1387	177	553	1346
Displacement, ..3000 Tons;	9	13·21	175	486	1382	192	533	1341	229	636	1253	252	700	1198
	10	12·12	241	602	1258	263	657	1208	314	785	1093	345	862	1024
Passage, ...3000 Miles.	11	11· 9	320	727	1116	350	795	1052	418	950	907	459	1043	819
	12	10·10	416	867	951	455	948	871	542	1129	693	596	1242	583
	8	23·10	148	694	1905	163	764	1855	195	914	1748	214	1003	1684
Displacement, ..4000 Tons;	9	20·20	212	883	1746	232	967	1685	277	1154	1546	305	1271	1460
	10	18·18	292	1095	1560	319	1196	1483	380	1425	1307	418	1567	1198
Passage, ...4500 Miles.	11	17· 1	388	1323	1351	424	1445	1253	506	1725	1031	557	1899	894
	12	15·15	504	1575	1108	551	1722	988	657	2053	716	722	2256	550
	8	31· 6	172	1075	2291	189	1181	2220	226	1412	2068	248	1550	1977
Displacement, ..5000 Tons;	9	27·19	245	1361	2074	270	1500	1980	322	1789	1784	354	1967	1663
	10	25· 0	336	1680	1824	370	1850	1705	441	2205	1457	485	2425	1303
Passage, ...6000 Miles.	11	22·17	448	2036	1534	492	2236	1390	587	2668	1079	646	2936	886
	12	20·20	581	2421	1209	639	2662	1030	762	3175	651	838	3492	416

Referring to the foregoing Table (H) it appears that a ship of 3000 tons' mean displacement, of which the index number is 862, will be propelled at ten nautical miles per hour, by 241 H.P., and that a passage of 3000 nautical miles will be performed in twelve days twelve hours, conveying 1258 tons of cargo, being equivalent to one day's work of $29\frac{5}{6}$ tons of shipping, and one day's work of $2\frac{7}{18}$ H.P. per ton of goods.

But if the index number of the vessel be reduced to 602, it appears that 345 H.P. will be required to attain the speed of ten nautical miles per hour, and the cargo will be reduced to 1024 tons, being equivalent to one day's work of $36\frac{8}{5}$ tons of shipping, and one day's work of $4\frac{2}{9}$ H.P. per ton of goods. Now, supposing the *cost* of freight to be proportional in the SHIPPING department to the amount of *tonnage*, and in the ENGINE department to the amount of *engine power* (H.P.) employed for a given time to do the work, it follows that the cost per ton of cargo on the passage referred to will be enhanced in the SHIPPING department proportionally to the numbers $29\frac{5}{6}$ and $36\frac{8}{5}$, or as 100 to 123, or 23 per cent., and in the ENGINE department proportionally to the numbers $2\frac{7}{18}$ and $4\frac{2}{9}$ or as 100 to 176, or 76 per cent.; on the whole, therefore, the cost of freight *per ton* will be enhanced probably about 50 per cent., or about the mean per centage of the two departments.

By the same process of investigation it will be found that with a vessel of 4000 tons' mean displacement, making a passage of 4500 nautical miles, at the rate of ten miles per hour, a reduction of the index number from 862 to 602 will enhance the cost of freight *per ton* about 60 per cent.; and, with a vessel of 5000 tons' mean displacement, making a passage of 6000 nautical miles, at the rate of ten miles per hour, a reduction of the index number from 862 to 602 will enhance the cost of freight *per ton* about 70 per cent.

The extent of variation, assumed in the above cases, in the *index numbers* of the vessels supposed to be employed, or this assumed extent of *falling off* in the index number of the same vessel under different conditions of efficiency, namely, a falling off from 862 to 602, in consequence whereof the cost of freight per ton on the passages referred to has been so greatly enhanced, viz.—50 per cent. on the 3000 mile passage; 60 per cent. on the 4500 mile passage; and 70 per cent. on the 6000 mile passage, is by no means an extreme case of variation, but such, as judging from experience, is likely to be of common occurrence, for on comparison of vessels of analogous class, and of which the length exceeds five times the breadth, the index numbers have been found to vary 30 per cent. and upwards, and it has been found that the index number of the same vessel, but in different conditions of efficiency, is liable to vary fully 20 per cent.

It now remains to be observed that in all the foregoing calculations the consumption of fuel per H.P. has been presumed to be constant, viz., at the rate of 4 cwt. per H.P. per day of 24 hours, the unit of power (H.P.) being taken at 132·000 lbs., raised 1 foot per minute, that is about 18 lbs. of coal per hour for each 132·000 lbs., moving 1 foot per minute, or 4½ lbs. per hour for each 33,000 lbs., moving 1 foot per minute, which rate of consumption is not generally realized in present marine engine practice, or, at least, it requires the boilers, and their management, to be of the first-rate order. It is, however, to be expected not only that improvement in boiler construction productive of greater economy of fuel, in proportion to the water evaporated, will be effected; but also that improved methods of applying the steam, or improved systems of working it, whereby a greater amount of power (H.P.) may be derived from a given

amount of evaporation, will be introduced in marine navigation; and, on the other hand, *impaired* efficiency in the boiler department of steam-ships, whereby the consumption of fuel becomes *increased*, is liable to occur. No definite limit can be assigned to such fluctuations; but, assuming them at 25 per cent. only, the consumption of coal per H.P., under different circumstances of engine and boiler construction, condition, and management, may be expected to fluctuate from 3 cwt. per H.P. per day to 5 cwt. per H.P. per day. Accordingly, the following Table (I) has been arranged and calculated for ships of 4000 tons' mean displacement employed on a passage of 4500 nautical miles,—the consumption of fuel being assumed, according to the construction or condition of the machinery, at 3 cwt., 4 cwt., and 5 cwt. per H.P. per day; and the index numbers, representing the locomotive efficiency of the vessels, being assumed at 862, 664, and 602, which, as before stated, are not extreme cases of fluctuation. The object of the whole investigation is to arrive at some general appreciation of the *extent* to which the COST of goods transport is affected by *differences* in the CONSTRUCTIVE MERIT of the steam-ship Stock; and the calculation is based on the assumption that the cost of goods transport *per ton* is approximately proportional to the amount of tonnage, and the amount of engine power employed for a given time to do the work.

TABLE I.

Mean Displacement, 4000 Tons; Passage, 4500 Nautical Miles.

Showing the commercial effect on the cost *of Freight per Ton, occasioned by differences in the original construction or subsequent working condition of the Hull, Engines, and Boilers.*

Consumption of Coal per H.P. per Day of 24 Hours.	Speed—per Hour.	Time of Passage.	Index Number, 862. Power.	Index Number, 862. Coal.	Index Number, 862. Cargo.	Index Number, 862. Cost of Cargo, proportional to 1 day's employment *per ton of freight* of		Index Number, 664. Power.	Index Number, 664. Coal.	Index Number, 664. Cargo.	Index Number, 664. Cost of Cargo, proportional to 1 day's employment *per ton of freight* of		Index Number, 602. Power.	Index Number, 602. Coal.	Index Number, 602. Cargo.	Index Number, 602. Cost of Cargo, proportional to 1 day's employment *per ton of freight* of	
	N. M.	D. H.	H. P.	TONS.	TONS.	TONS.	H. P.	H. P.	TONS.	TONS.	TONS.	H. P.	H. P.	TONS.	TONS.	TONS.	H. P.
3 Cwts. per H.P. per Day.	6	31· 6	64	300	2186	57	0·91	82	384	2126	59	1·21	90	422	2099	60	1·84
	7	26·19	100	402	2099	51	1·23	130	522	2009	53	1·73	143	575	1970	54	1·94
	8	23·10	148	520	1992	47	1·74	195	686	1862	50	2·46	214	752	1810	52	2·77
	9	20·20	212	662	1857	45	2·38	277	866	1690	49	3·41	305	953	1618	52	3·93
	10	18·18	292	821	1698	44	3·28	380	1069	1486	50	4·79	418	1176	1394	54	5·62
4 Cwts. per H.P. per Day.	6	31· 6	64	400	2136	59	0·94	82	512	2062	61	1·24	90	562	2029	62	1·39
	7	26·19	100	536	2032	53	1·32	130	696	1922	56	1·81	143	766	1874	57	2·04
	8	23·10	148	694	1905	49	1·82	195	914	1748	54	2·61	214	1003	1684	56	2·98
	9	20·20	212	883	1746	48	2·53	277	1154	1546	54	3·73	305	1271	1460	57	4·35
	10	18·18	292	1095	1560	48	3·51	380	1425	1307	57	5·45	418	1567	1198	63	6·54
5 Cwts. per H.P. per Day.	6	31· 6	64	500	2086	60	0·96	82	641	1998	68	1·28	90	703	1958	64	1·44
	7	26·19	100	670	1965	55	1·36	130	871	1835	58	1·90	143	958	1778	60	2·15
	8	23·10	148	867	1818	52	1·91	195	1143	1634	57	2·80	214	1254	1559	60	3·22
	9	20·20	212	1104	1636	51	2·70	277	1443	1402	59	4·12	305	1589	1301	64	4·88
	10	18·18	292	1369	1424	53	3·84	380	1781	1130	66	6·30	418	1959	1002	75	7·82

From this Table (I) we arrive at the following conclusions:—1st. That a ship of 4000 tons' mean displacement, of which the INDEX NUMBER is 862 and consumption of FUEL 3 *cwt. per H.P. per day*, will make a passage of 4500 nautical miles, at the speed of ten miles per hour, by one day's employment of 44 tons of shipping and $3\frac{23}{100}$ H.P. *per ton* of freight; but, if the INDEX NUMBER be reduced to 664, and the consumption of fuel be increased to 4 cwt. per H.P. per day, the passage will be made by the employment of Tonnage and Power equivalent to one day's employment of 57 tons of Shipping and $5\frac{45}{100}$ H.P. *per ton* of freight: that is, the cost of freight will be enhanced in the Shipping department in the proportion of 44 to 57, or 100 to 130 or about 30 per cent.; and in the Engine department in the proportion of $3\frac{23}{100}$ to $5\frac{45}{100}$, or as 323 to 545, or 100 to 170, or about 70 per cent.: that is, taking the mean per centage of the two departments, the cost of freight per ton will be enhanced about 50 per cent. in consequence of the above-mentioned *inferiority* in the original construction or subsequent *falling off* in the working condition ofthe ship employed.

Again, if the index number of the vessel be reduced from 862 to 602, and the consumption of fuel increased from 3 cwt. to 5 cwt. per H.P. per day, it will appear by a similar process of calculation to that above-exemplified, that the cost of freight *per ton* will be enhanced about 100 per cent., or doubled, in consequence of such inferiority of original construction, or subsequent falling off in the working condition of the ship employed.

It may further be observed that the *inferior* ship above-mentioned, if fitted to run at *eight miles* per hour,

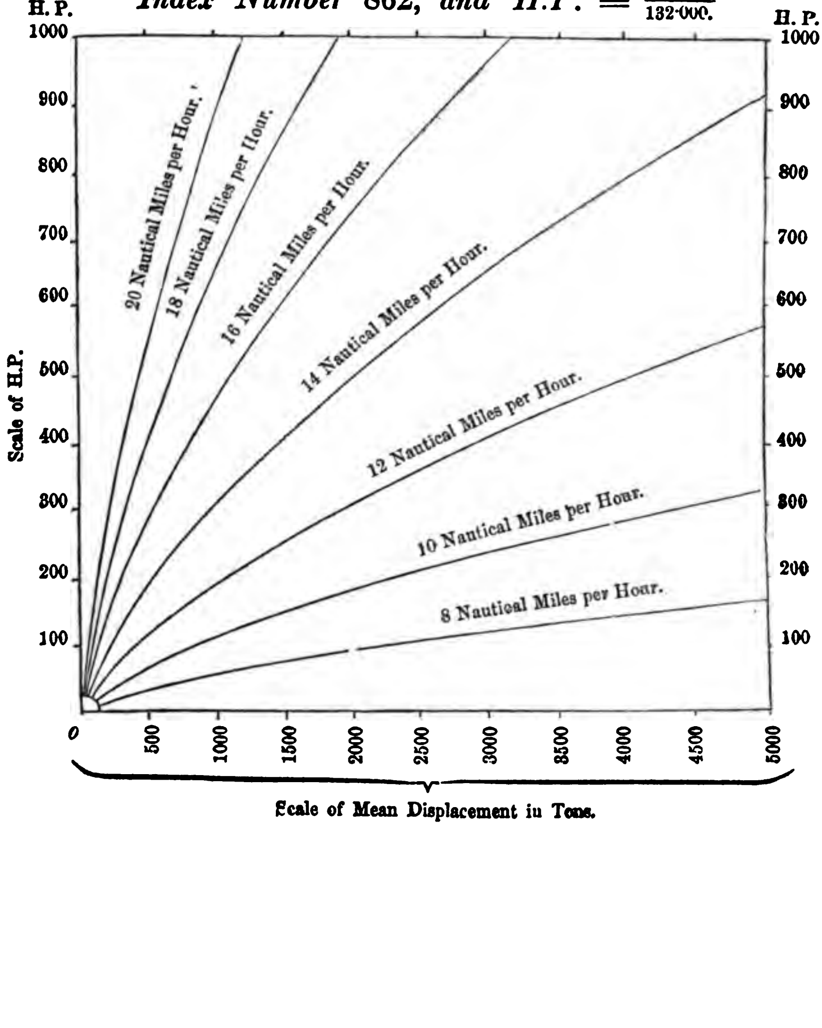
would convey freight at about the *same scale* of cost as would be effected by the *superior* ship if running at *ten miles* per hour, though, as above shown, incurring *double* the cost per ton of goods conveyed, if running at the same speed. Hence we may infer the advantage that would accrue to steam-ship companies from having a variety of service on which to employ their stock, demanding different rates of speed, according to the unavoidable differences of their respective ships.

The foregoing examples as to the difference of COST *per ton* of freight, at which the same service, at a given rate of speed, would be performed by different vessels, or by the same vessel under different conditions of efficiency, sufficiently demonstrate that the comparative CONSTRUCTIVE MERIT of new ships and the upholding of STOCK ships in their most perfect condition, are points of management in steam-ship DIRECTION vitally affecting the commercial prosperity of any steam-ship enterprise, and constitute considerations, under which the subject-matter of the foregoing exposition assumes an important bearing, not merely on private, but even on national interests, dependant as the interests of all Commercial Nations now are on ocean navigation,—an issue pointing out the necessity for adopting *some* recognised method of calculation and STANDARD MEASURE of *comparison* whereby the relative constructive merit of steam-ships may be satisfactorily determined, and whereby the FAME which may justly attach to pre-eminence in the nationally-important art of STEAM-SHIP CONSTRUCTION may be justly awarded where, and where only, such credit may be justly due.

APPENDIX.

THE annexed DIAGRAM exemplifies a system whereby the mutual relation of Displacement, Power, and Speed may be shown generally for vessels of any size. The base line of the Diagram is divided into a scale of equal parts, representing the mean displacements; and from certain determined points thereon, as at the points of the scale marked 500, 1000, 2000, 3000, &c., *vertical* lines are drawn of a length proportional to the variations of power (H.P.) (*calculated* as in Tables A, B, C, D,) required to propel vessels of these respective displacements at any specified rate of speed; and a curve line is then drawn through the *extremities* of the said vertical lines. If, now, from the point on the base line which represents any particular amount of mean displacement, a vertical line be drawn up to the curve, the length of the said vertical line, measured on the scale of H.P., will represent the power required to propel the vessel at the speed for which the curve may have been drawn. For example, a ship of 750 tons' mean displacement, of which the index number is 862, requires about 50 H.P. for eight nautical miles per hour; about 100 H.P. for ten miles; 160 H.P. for twelve miles; 260 H.P. for fourteen miles; 400 H.P. for sixteen miles; 550 H.P. for eighteen miles; and 760 H.P. for twenty nautical miles per hour,

Index Number 862, *and H.P.* $= \frac{\text{P.V.}}{132\cdot000}$.



Scale of Mean Displacement in Tons.

Table *showing the number of* **Revolutions**, *per minute, which will be required in order that a* **Screw-Propeller** *of a* given pitch *may advance at a* given speed *(slip not included).*

Speed per Hour	Pitch of Screw in Feet, *(Exclusive of any allowance for Slip).*																									
	2	2½	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
N. M.																											
5	253	203	169	127	101	84	72	63	56	51	46	42	39	36	34	32	30	28	27	26	24	23	22	21	20	19	19
6	304	243	203	152	122	101	87	76	68	61	55	51	47	44	41	38	36	34	32	30	29	28	26	25	24	23	23
7	355	284	237	177	142	118	101	89	79	71	65	59	55	51	47	44	42	39	37	35	34	32	31	30	28	27	26
8	406	324	270	203	162	135	116	101	90	81	74	68	62	58	54	51	48	45	43	41	39	37	35	34	32	31	30
9	456	365	304	228	183	152	130	114	101	91	83	76	70	65	61	57	54	51	48	46	43	41	40	38	37	35	34
10	507	406	338	253	203	169	145	127	113	101	92	84	78	72	68	63	60	56	53	51	48	46	44	42	41	39	38
11	558	446	372	279	223	186	159	139	124	112	101	93	86	80	74	70	66	62	59	56	53	51	48	46	45	43	41
12	608	487	406	304	243	203	174	152	135	122	111	101	94	87	81	76	72	68	64	61	58	55	53	51	49	47	45
13	659	527	439	330	264	220	188	165	146	132	120	110	101	94	88	82	78	73	69	66	63	60	57	55	53	51	49
14	710	568	473	355	284	237	203	177	158	142	129	118	109	101	95	89	84	79	75	71	68	65	62	59	57	55	53
15	760	608	507	380	304	253	217	190	169	152	138	127	117	109	101	95	89	84	80	76	72	69	66	63	61	58	56
16	811	649	541	406	324	270	232	203	180	162	147	135	125	116	108	101	95	90	85	81	77	74	71	68	65	62	60
17	862	690	575	431	345	287	246	215	192	172	157	144	133	123	115	108	101	96	91	86	82	78	75	72	69	66	64
18	913	730	608	456	365	304	261	228	203	183	166	152	140	130	122	114	107	101	96	91	87	83	79	76	73	70	68
19	963	771	642	482	385	321	275	241	214	193	175	161	148	138	128	120	113	107	101	96	92	88	84	80	77	74	71
20	1014	811	676	507	406	338	290	253	225	203	184	169	156	145	135	127	119	113	107	101	97	92	88	84	81	78	75

Note.—To compensate for **Slip** the Revolutions of the Propeller may be increased about 10 per cent.